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Editorial
Editor: **Ben Mansill** ben.mansill@futurenet.com
Senior Journalist: **Shaun Prescott**
Journalist: **Joel Burgess**
Journalist: **Harry Domanski**
Journalist: **Stephen Lambrechts**
Journalist: **Sharmishta Sarkar**
Creative Director: **Troy Coleman**
Designer: **Tim Frawley**

Contributors
Jon Bolding, Matt Bolton, Christian Cawley, Ian Evenden, Wes Fenlon, Leana Hafer, Kenny Hemphill, Luke Kemp, John Knight, Mayank Sharma, Shashank Sharma, Tom Sykes, Chris Szewczyk, Oscar Taylor-Kent, Jarred Walton, Mark Williams, Darren Yates

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Advertising
Group Advertising Manager: **Cameron Ferris**
cameron.ferris@futurenet.com

Management
Managing Director: **Neville Daniels**
Sales Director: **Paul Marttila**

Printed in Australia by IVE

Distributed in Australia and NZ by Ovato
ovato.com.au

ISSN 0725-4415

Future Publishing Australia
PO Box 1077 Mount Street,
North Sydney, NSW 2059
Tel: (02) 9955 2677 **Fax:** (02) 9955 2688
Email: apcmag@futurenet.com
Web: www.apcmag.com

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EDITORIAL

WELCOME TO APC

EDITORIAL

Let's go shopping!

Or not...

It's a very rare and special time in the world of the PC. We're witnessing above-average generational performance leaps with GPUs, a remarkable battle for the CPU space well into its third year, exciting new PCIe 4 SSDs, motherboards with loads of lanes, monitors with extreme specs, and RAM hitting ridiculous speeds. It's wonderful. Well, it *could* be wonderful. But it's not. Because you just can't buy a lot of this stuff without a long wait, and/or some compromise on what you really wanted.

You know the situation. You may well be on a waiting list for something. Odds are, you are. We've covered this from a few angles this month. Joel (page 17), Jared (page 19) and Mark (page 64) look at the issue, the immediate effects and the complex web of reasons why it's happening, and the likely outcomes. We still can't say when things will improve, though.

As you may have heard, it's an issue affecting the world beyond the PC. Car manufacturers are seeing shortages of essential chips for vehicles, and Tesla recently shut down one of its production plants for two weeks very likely due to chip shortages (though that wasn't Tesla's *official* reason). And you can bet it's also affecting military production, and many other major industries. U.S. President Biden was convinced enough of the urgency to resolve this that he's appointed a task force to look at long-term solutions.

While there are many interlinked root causes, for our PC corner of the world a very serious concern is that a huge proportion of the world's chips come from a single company – TSMC in Taiwan. If you've ever wondered why the U.S. isn't keen on removing itself from the defence pact it has with Taiwan... well, this is part of it – though this has really only fallen into focus recently.

Besides operating several fabrication plants for many different spec ICs (differentiated mostly by process size, ie. the nanometers ('nm') we're always talking about), TSMC has the world's only 7nm plant – and that's where the choke point lies for a big chunk of PC gear. AMD of course uses TSMC exclusively for its 7nm PC CPUs and GPUS – but the same is true of the AMD CPU and GPU that goes into every single PlayStation 5 and Xbox S and X. And it's widely known, off the record of course, that both Sony and Microsoft have minimum order agreements which AMD is obliged to fulfil over its own Ryzen and Radeon products. Nvidia is in the same situation with its 30-series cards and chip partner Samsung. Too much demand, too little capacity.

TSMC is close to finalising plans for a huge 7nm fab in the U.S. But it will be years before that's online. In the meantime we'll continue to point at COVID, crypto miners and scalpers as to why we can't buy the gear we want, but it's a complex web that will stay tangled for many months or even years to come.

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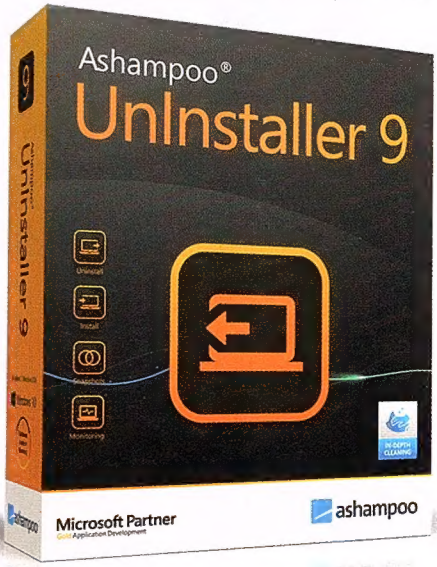

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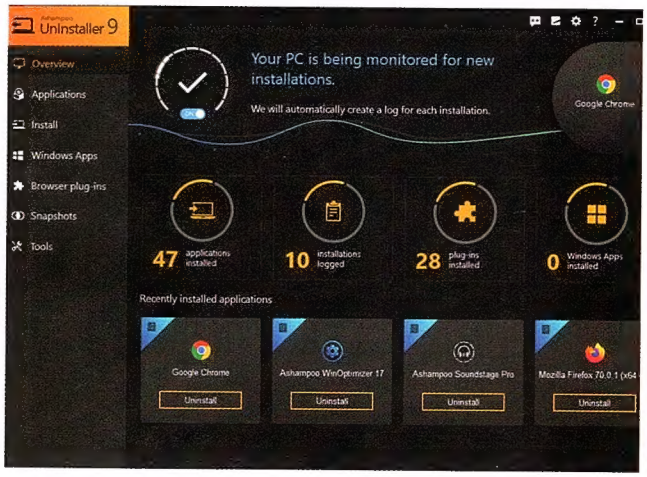

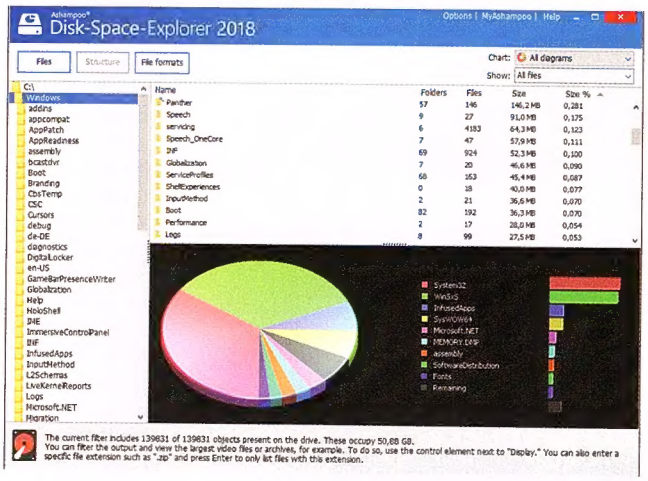

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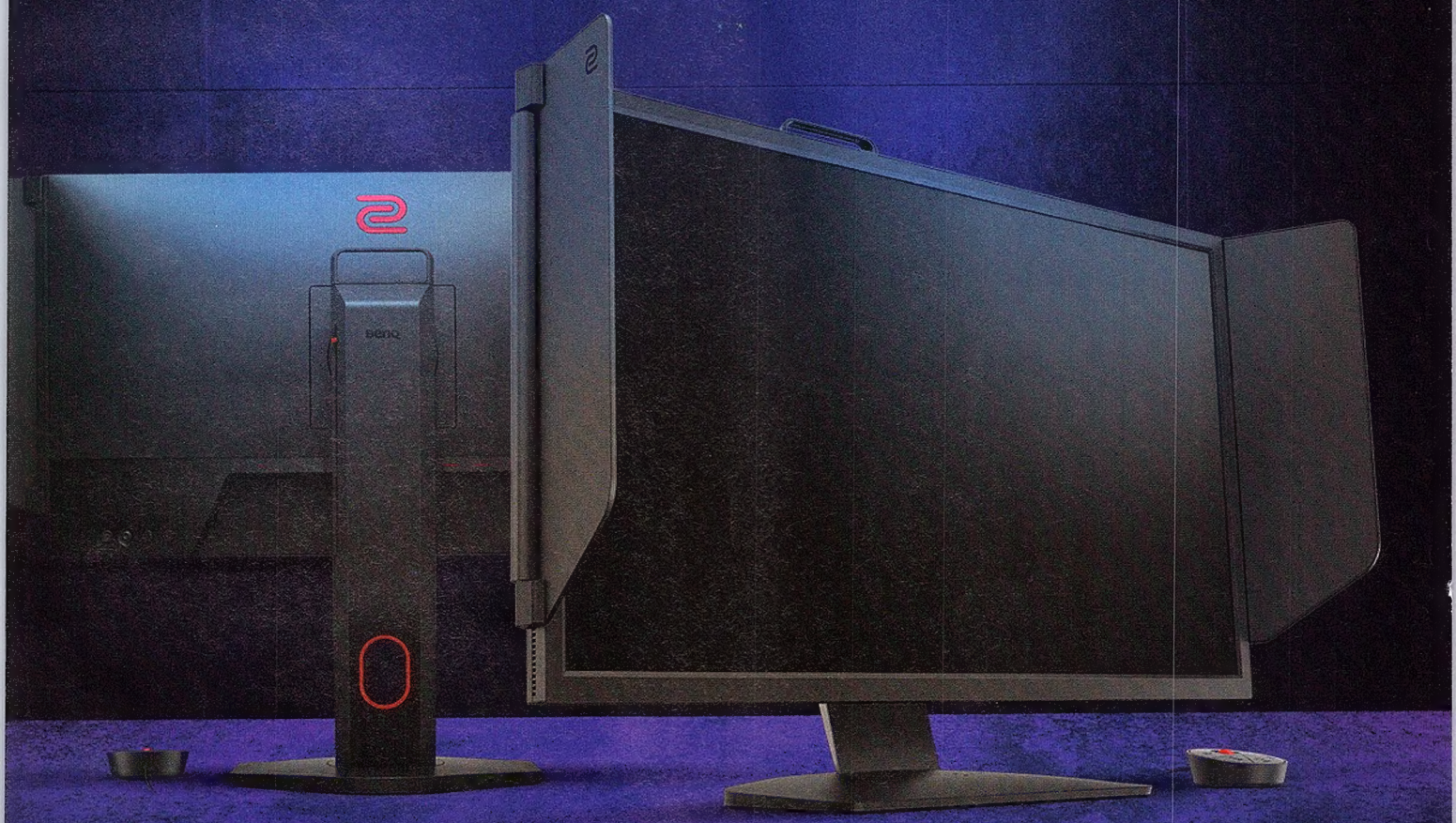

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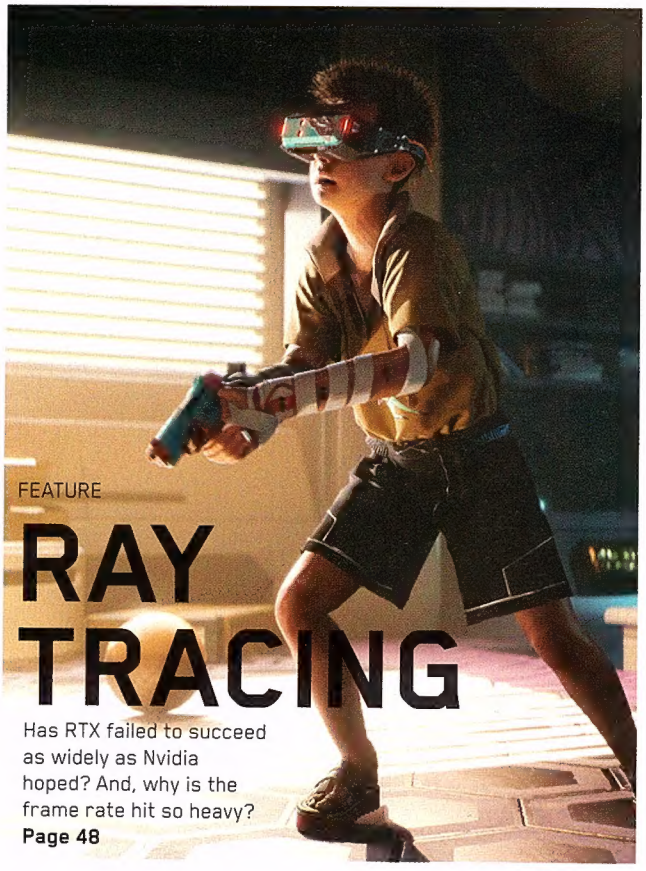

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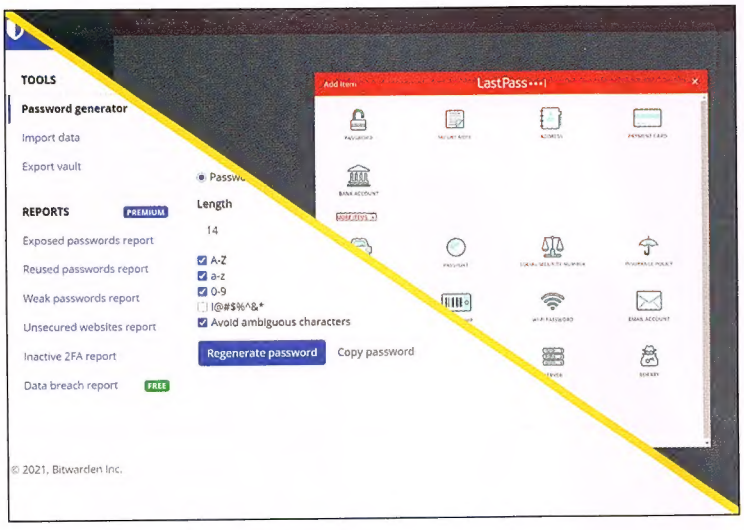

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You will see this award if a reviewed product has scored four out of five stars. It means most people can expect satisfying performance from the product, and that we would use it ourselves.

Inside *APC*

Find out all about *APC*'s editorial policies, test practices, how to read the benchmark results, and more.

APC is Australia's oldest consumer technology magazine – having been consistently in print for forty years, since our first issue way back in May 1980 – and we take that heritage and responsibility very seriously. While our focus is obviously on the personal computer the very definition of the PC has changed and shifted markedly since the early 1980s. As such, we touch on many other areas of tech, too, from smartphones and apps to peripherals, accessories, and beyond. We have two goals: to find the best modern tech and to help you make the most of it.

We're also an open church in terms of platforms. We know most people aren't wed to a single brand's products and use a variety of devices. And, like you, *APC*'s journalists want to know what's good in tech – no matter what platform it resides on.

Independent reviews

Championing technology doesn't mean we're unrelenting yes-men and -women, however, and *APC* aims to be as objective as possible in all our coverage. That means identifying the best products from multiple perspectives – the best performance, best value and best features and, ideally, the products that offer the best mix of these three attributes.

As a matter of policy, reviews published in *APC* are not shared with product-makers prior to print. We will contact vendors under certain conditions; for example, if we have a problem testing a product that seems to indicate it may be faulty, or to invite a vendor to clarify how a particular feature works. If an *APC* reviewer has any potential conflicts of interest involving a brand, the review will always be assigned to another writer.

"APC strives to conduct the most rigorous, objective scientific tests and benchmarks we can so as to make our reviews as unbiased as possible."

Labs testing

APC strives to conduct the most rigorous, objective scientific tests and benchmarks we can so as to make our reviews as unbiased as possible. We use a variety of tools and programs for this, including many freely available benchmark suites for assessing media encoding, general system performance including storage read and write speeds, gaming and battery life.

In most cases, for the benchmark results published in *APC*, you can assume that higher is better. There are certain tests that deviate from this rule where the opposite is true; in those cases, we've flagged the results with a note explaining as such.

We use both tables and graphs for displaying results; the latter offers better ease-of-readability, but tables are more compact, so we use these in most cases where thoroughness is preferred.

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TECHNOTES

ALL THE NEED-TO-KNOW TECH NEWS

BIG MONEY

Intel ordered to pay US$2.2 billion in damages

Paying up for patent infringement.

A federal jury in Waco, Texas, ruled on March 3rd that Intel must pay US$2.18 billion in damages to VLSI, a semiconductor design firm, for violating two of its patents. Damages for one patent violation weigh in at US$1.5 billion, while the other totals US$675 million. The broader case is still ongoing, though, as VLSI has sued Intel in several states, spanning California, Delaware, and Texas, for damages associated with six other alleged patent violations.

Intel's most recent 10K filing lists the VLSI lawsuits as ongoing litigation, noting that VLSI seeks a total of US$7.1 billion in damages from all eight alleged violations, along with future royalties, attorney's fees, costs, and interest. Intel predicts that totals up to US$11 billion, collectively.

Intel commented on today's ruling, saying to *Tom's Hardware*, "Intel strongly disagrees with today's jury verdict. We intend to appeal and are confident that we will prevail."

According to the Waco Tribune-Herald, one patent pertains to saving computer power, while another pertains to increasing the speed of the processor. We tracked down the patents, with the '759 patent' relating to clock speed management, while the '373 patent' describes a method to reduce the memory's minimum operating voltage.

VLSI originally purchased the patents in question from NXP Semiconductors, which will also get an unspecified portion of the awards. However, the patents originated with Freescale Semiconductor Inc. and SigmaTel Inc., both of which were purchased by NXP Semiconductors.

Intel has denied that it violated the patents, and, along with Apple, has previously filed an antitrust lawsuit against VLSI's parent company, Fortress, claiming the company had unlawfully aggregated patents.

Intel's lawyers said in the closing arguments that VLSI has no products and that its only source of revenue is from the lawsuits, obviously implying the company is merely a patent troll.

To keep things in perspective, while the US$2.2 billion in damages is obviously high, Intel raked in US$77.9 billion in revenue during 2020, so it's a manageable sum. However, it is significantly higher than the US$1.2 billion fine Intel was slapped with for antitrust behaviour against AMD a decade ago, and the company still disputes that fine in court today.

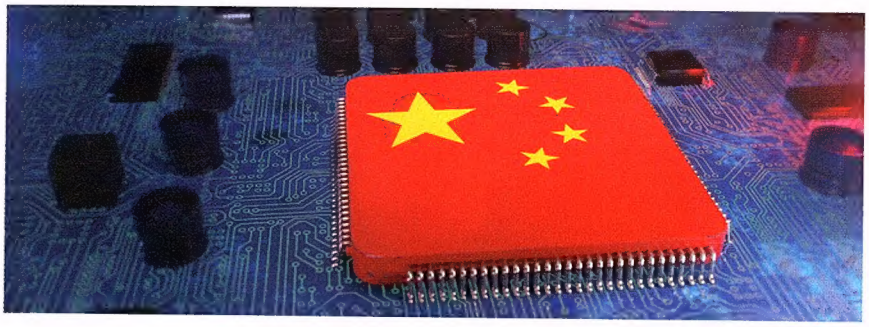
LastPass free plan to be more restrictive

Will only work on a single platform.

LastPass is rolling out a change to its free plans that will affect users drastically. Specifically, it'll limit the kind of devices users can run the app on from March 16th, 2021. Users will have to select their device type by logging into their account.

Depending on which device you choose, you'll automatically be opted into the mobile or computer type. and they'll be offered three chances to switch before needing to choose or trade up to the premium plan.

To clarify, you could use two types of devices on the previous plan, now you can use an unlimited number of devices, albeit limited to one type in pre-defined classes.



Pic: Getty

China's buying used chip-making equipment

To skirt US restrictions.

The U.S. imposed new sanctions on SMIC, the largest semiconductor manufacturer in China, in September 2020 to prevent it from purchasing new chip-making equipment. Used chip-making equipment sellers in Japan aren't subject to those same restrictions, however. Nikkei Asia said those sellers have struggled to keep their products in stock, which has led to significant price increases over the last year. The value of critical equipment such as lithography systems reportedly tripled in that timeframe.

Nikkei Asia said that "nearly 90 percent of used machines appear to be headed to China," per a source at Mitsubishi UFJ Lease & Finance, and that another anonymous source at an unidentified used equipment dealer claimed, "machines that were basically worthless several years ago are now selling for 100 million yen ($1,200,000)."

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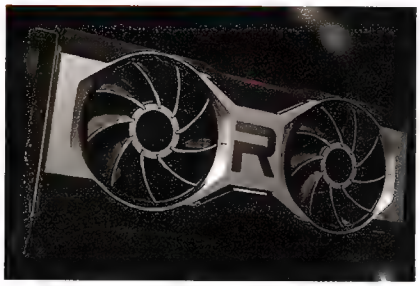


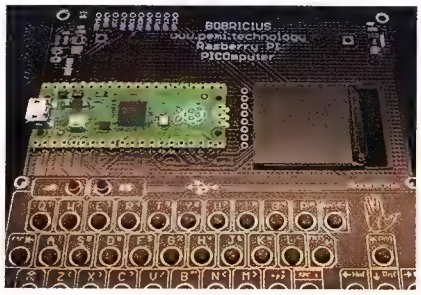
AMD Radeon RX 6700 XT announced

Navi 22 targets RTX 3060 Ti and 3070 performance.

The AMD Radeon RX 6700 XT comes in with the highest GPU clocks we've to date, 2,424MHz. The RX 6800 XT and RX 6900 XT both have 2,250MHz game clocks, though in actual benchmarks, we've seen speeds of more than 2500MHz already – the Game Clock is more of a conservative boost clock. Even with a drop down to 40 CUs (from 60 CUs on the RX 6800), the higher clock speeds should prove relatively potent.

Raw theoretical performance sits at 12.4 TFLOPS, and assuming AMD uses 16Gbps GDDR6 again (which is likely), it will have 384GBps of bandwidth. Except, it still has a honking 96MB L3 Infinity Cache.

Pic: Bobricius



Doomsday Communicator powered by Raspberry Pi

The end of the world doesn't mean we can't keep in touch.

The Raspberry Pi Pico is turning up in many imaginative projects, and the latest to the list is a long-range wireless chat "Doomsday Communicator" from Bobricius that features a simple QWERTY keyboard and a small IPS LCD display.

Bobricius' Raspberry Pi PICOmputer is the latest in their ARMACHAT long-range radio messenger boards. Powered by a single 18650 Lithium-Ion battery, ARMACHAT boards send messages over a radio connection, with frequencies and license requirements varying depending on where you are in the world. They can also be used in a mesh network with other users, handy if there's ever an apocalypse.

There isn't much information right now, and it is early days to estimate a release date. Based on the previous models, we expect prices to be around $200.

PRIVACY

Google says it's no longer interested in tracking users

Google claims preserving user privacy is now a top priority.

Google's plans to phase out tracking cookies last year were met with skepticism. However, the company has once again reiterated its intentions to help protect user privacy.

Tracking cookies were initially pitched as a means of creating a more personalised web experience. Over time, however, they were subverted for unscrupulous uses and these days are mostly seen as a threat to online privacy.

"Today, we're making explicit that once third-party cookies are phased out, we will not build alternate identifiers to track individuals as they browse across the web, nor will we use them in our products," said David Temkin, Google's Director of Product Management for Ads Privacy and Trust.

Back when Google, which was one of the pioneers of the tracking cookie, announced plans to slowly discontinue the use of cookies, many privacy advocates agreed that Google probably had another trick up its sleeve.

"Keeping the internet open and accessible for everyone requires all of us to do more to protect privacy – and that means an end to not only third-party cookies, but also any technology used for tracking individual people as they browse the web," said Temkin.

Samsung has troubles restarting Texas fab

Chip shortages to get worse.

Pic: Samsung

Samsung Foundry, Infineon Technologies, and NXP Semiconductors have not yet restarted operating their fabs in Austin, Texas, as they need time to clean them up and configure them again. The idling fabs will further contribute to the ongoing global shortage of chips, which could affect the pricing of final products, such as SSDs.

Due to power outages caused by unprecedentedly cold weather and a winter storm, the Austin Energy power grid asked its biggest consumers, such as Samsung Foundry and other makers of semiconductors, to temporarily shut down their fabs in a bid to ensure that enough power was supplied to homes in late February. While it is possible to briefly turn off a chip production facility, it is extremely hard to restart it. ■

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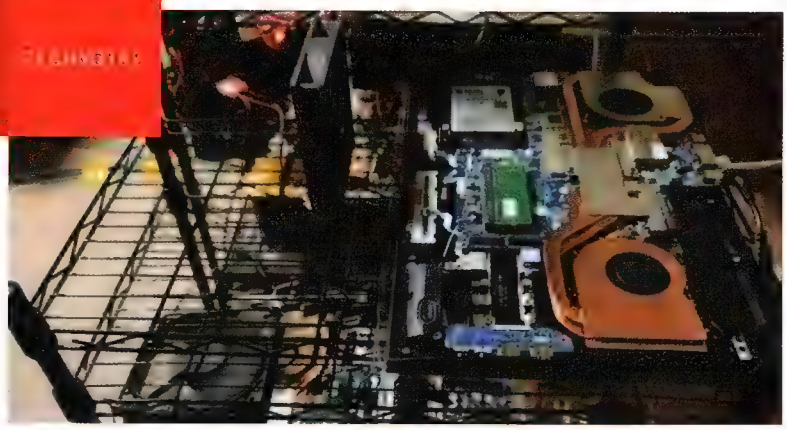
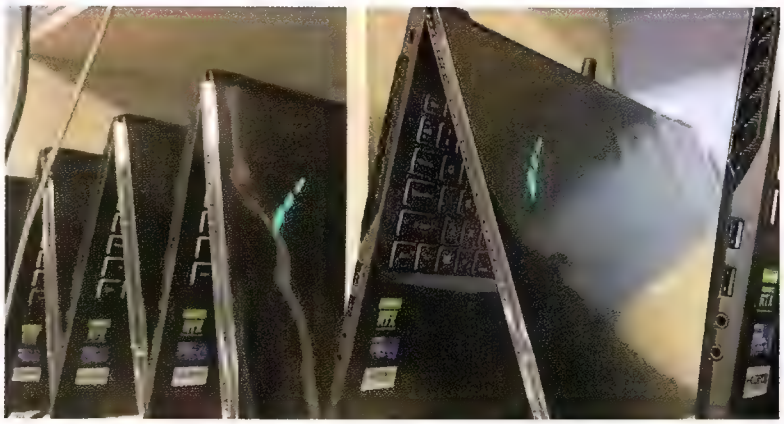




TECH BRIEF

Laptop mining farms are the latest craze

Here's the math behind the madness.

What do you do when you want to mine Ethereum and can't buy any of the best graphics cards? For some users, the latest solution is to turn to laptop mining. We were skeptical the first time we heard people were using laptops to mine in bulk, but Weibo user BTCer has posted multiple images and even a video indicating this is the real deal. But given that these new farms use pricey laptops, how long would it take to break even, or turn a profit?

There are varying results, but memory bandwidth is a major factor in overall hashing performance. All of the RTX 20-series GPUs with 8GB of GDDR6 memory end up right around 45MH/s after tuning, while the desktop RTX 3060 Ti and 3070 manage 60MH/s. The mobile RTX 3060 will only have a 192-bit memory interface, which means performance will drop by 25 percent, and that puts it right around the same 45MH/s as the desktop 20-series parts.

The good news – for the laptops, at least – is that lower GPU clocks are generally okay, and memory overclocks aren't nearly as demanding in terms of power and heat. The mobile RTX 3060 appears to use around 80-90W while mining, which a decent cooling solution ought to be able to handle. Can it handle running that way 24/7, though? Probably not without additional help, which is also something other laptop miners seem to be exploring.

The laptops featured in most of these images appear to come from whitebook vendor Hasee. The best estimate of pricing we've found indicates each laptop costs around US$1,780, though bulk discounts for hundreds of laptops might mean they can get them for US$1,500 or less. Still, that's a lot of money for a laptop that does around 40-45MH/s.

Current estimates for Ethereum mining indicate each laptop would generate around US$8.40 per day, with power costs of approximately US$0.26. Given the volatile nature of cryptocurrencies, that can go up or down quite quickly. But, at the present rate, it would still take 220 days to break even. And that's not accounting for costs related to rental space, racks, cooling fans, hardware replacement, and other requirements.

The long-term prospects of such an approach look questionable at best. But user BTCer doesn't seem to care. In one post (translated via Google), he notes, "I used to work in a sweatshop... to support the house, now the cyber sweatshop is 7/24, and I lie down every day to sell coins at the end of the month, and repay the mortgage, which is beautiful."

Even if we ignore the long-term prospects for such an approach, there's still the question of how BTCer managed to acquire hundreds of laptops. Never mind the cost (perhaps half a million dollars or more); who's selling miners all of these gaming laptops? Well, based on the images, Hasee. But the same thing is happening with desktop graphics cards as well.

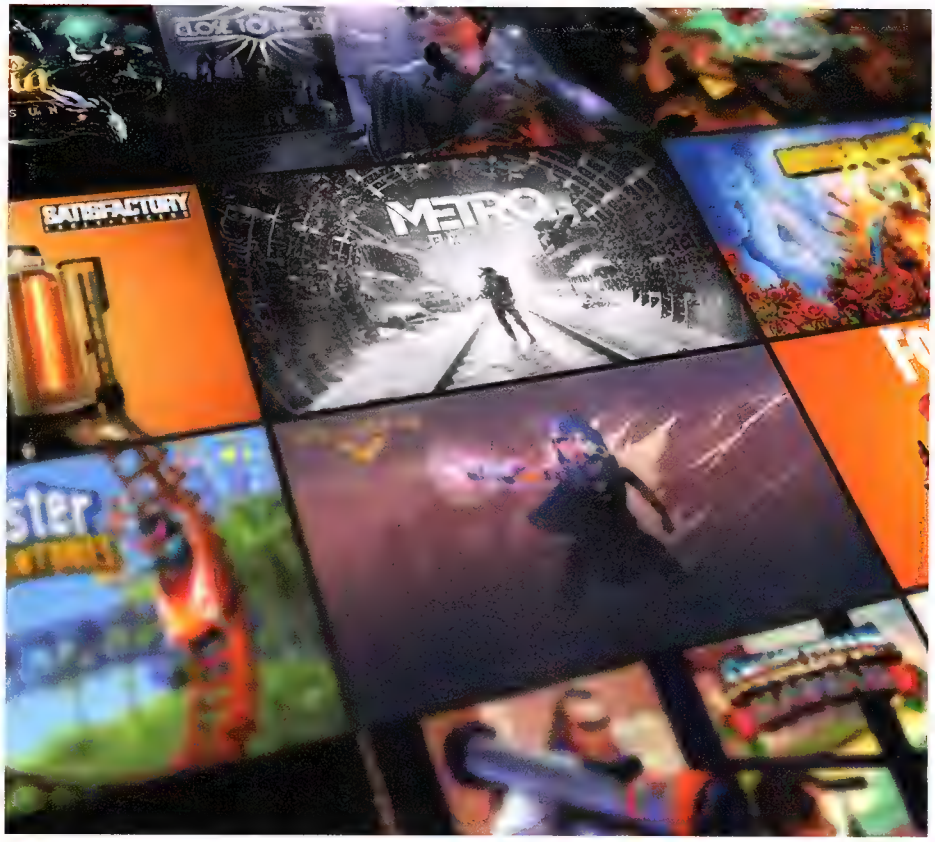
Everywhere online is sold out, but images of GPU mining farms with dozens and even hundreds of identical graphics cards routinely pop up online, which suggests the graphics card manufacturers are likely selling directly to miners, who are almost certainly paying much more than the normal price.

JARRED WALTON ■

THE CHOICE OF CHAMPIONS
REPUBLIC OF GAMERS
BEHOLD THE BEASTS
ASUS RADEON™ RX 6000 SERIES
ROG Strix
This frame-crunching colossus is a ferocious blend of industry-leading Axial-tech cooling, high-end power delivery , and a plethora of creature comforts. The ideal choice for air-cooled gaming rigs.
ROG Strix LC
Deep in ASUS R&D labs, engineers theorized the optimal thermal solution for AMD's latest RDNA™ 2 Architecture. The beast that emerged is a liquid-cooled leviathan capable of drawing maximum performance out of the new chips, while remaining completely cool and quiet.
TUF Gaming
This tenacious beast boasts a tough metal exterior, super-efficient cooling, and TUF components selected for maximum durability. It's a mean machine ready for unbridled action for years to come.
ASUS

OPINION

APC'S EXPERTS COVER THE HOT TOPICS



END USER

The way we get games has changed forever, and may change games

With the proliferation of free game giveaways and affordable subscription services, games will need to work harder for attention, writes Shaun Prescott.

Once upon a time you'd have to actually leave the house to buy a videogame, and once you got to the store, you'd need to fork out around $100 for the latest blockbuster. Things have definitely changed of late, though: physical games seem increasingly antiquated, and digital storefronts are raking it in, with games industry analysis company Newzoo claiming a whopping 91 percent of the US industry's 2020 revenue was made digitally.

Not surprising really. What may surprise others is that people are buying games at all. Free game giveaways are hardly a new phenomenon – publishers and developers have done it on Steam for years, and uh, remember magazine covermounts? – but the Epic Games Store has made it a weekly institution. Since late 2018 it has given away over 170 games, and they're not even bad ones: the list includes *Grand Theft Auto 5*, *Watch Dogs 2*, *Kingdom Come: Deliverance* and *Just Cause 4*, just to name a few high profile examples.

I've claimed a bunch of these free games and installed none of them; some weeks I don't even bother claiming the game. The *Mega Man* aping roguelike *20XX* does look cool, but is it worth opening a new tab in my browser? Not a negligible question. I think I'll buy it on Switch instead.

It's obviously a boon for people who don't have a lot of disposable money to spend on games, and it's also brilliant for people who don't play a lot of games but like to dabble. It's good for the consumer, but is it good for the industry? No one seems to have a definitive answer on this, though there's lots of gut feelings.

For my two cents, the combination of all these free games with the subscription smorgasbord of Xbox Game Pass tends to cultivate a grazer's mentality. Aside from games I've needed to finish for review, I don't think I've played more than the first 20 minutes of anything for the past 12 months. Once upon a time I would have persevered with *Cyber Shadow* – now I just move on when it gets too tough.

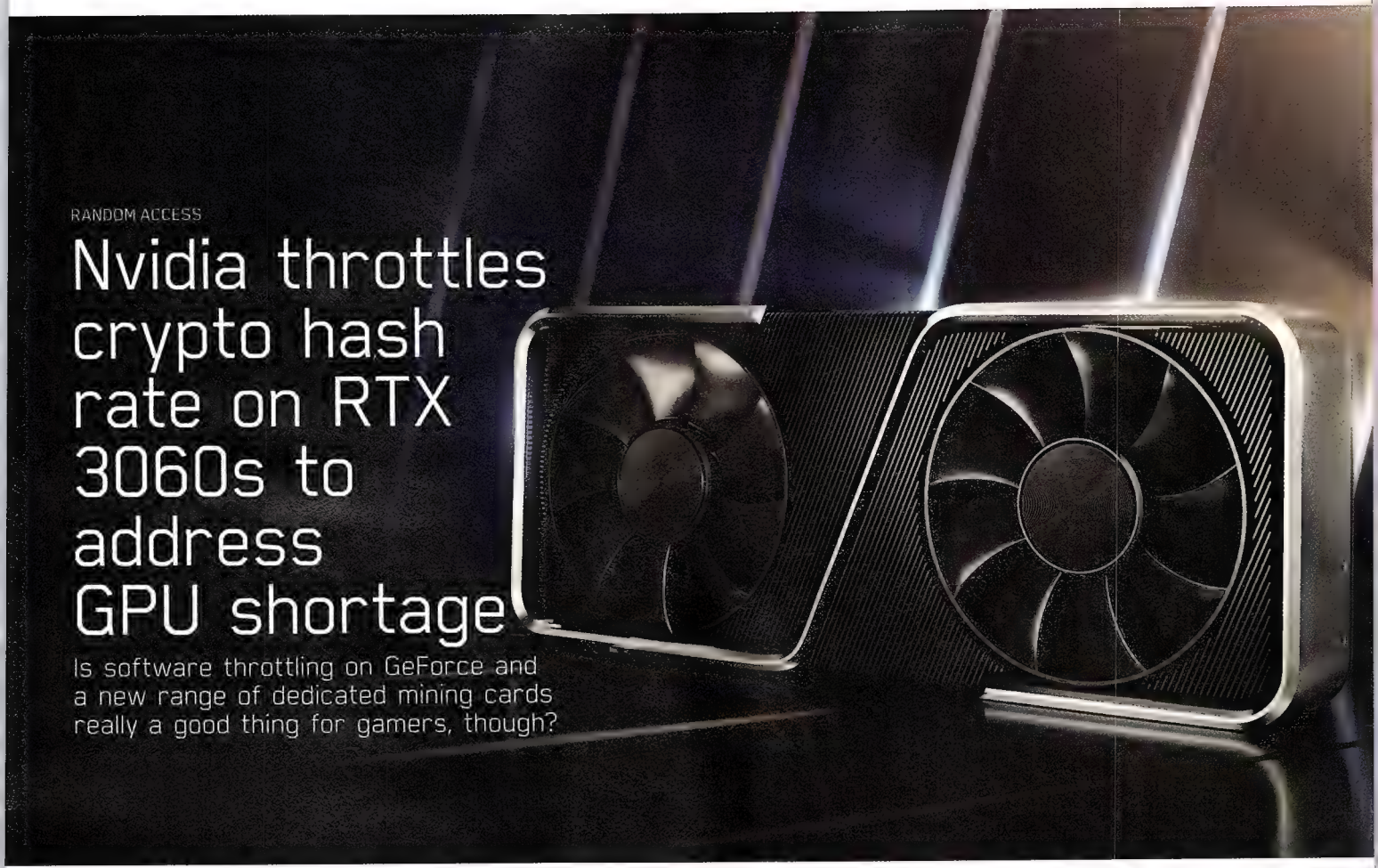
Meanwhile, I think the success of Xbox Game Pass, in concert with whatever meaningful competition arrives down the line, will probably show some influence on the way games are developed. Will games become shorter and more immediately gratifying? Will new genres emerge to accommodate this new attention economy?

There's also the question of who gets paid. The logic behind Epic Games' free games varies depending on what the title is, but there's no transparency on who gets paid and how much. As for Microsoft's Game Pass service, that changes on a game by game basis, according to Xbox leader Phil Spencer. "Our deals are, I'll say, all over the place," he told *The Verge* last year. "That sounds unmanaged, but it's really based on the developer's need." He goes on to say that it can be a good thing for small or medium devs to get a nice lump sum and exposure at launch – which rings true.

Big budget game releases won't cease to be events, and Sony and Nintendo both seem determined to carry the flame for full-priced tentpole releases. Event titles like *Cyberpunk 2077* and *The Last of Us Part Two* aren't going away, and *Halo Infinite* will be an "event" despite it costing as little as $10 for a month of Xbox Game Pass. But with free-to-play games, free game giveaways, and the 100+ games available on subscription services, it feels like any title that makes too great a demand on the player's patience and perseverance may suffer. ■

Nvidia throttles crypto hash rate on RTX 3060s to address GPU shortage

Is software throttling on GeForce and a new range of dedicated mining cards really a good thing for gamers, though?



Next generation GPUs have been difficult to get a hold of since launching in 2020. Whether it's the global shortage of silicon, improved generational performance of the latest cards, the increased demand and supply chain complications from COVID-19, or the recent resurgence of the crypto bull market that is driving the card shortage – gamers are are missing out on next-gen gaming experiences because supply is just not able to keep up with demand.

So it's perhaps a little surprising that despite this ongoing shortage, Nvidia managed to turn over US$3.2 billion in revenue on gaming products in the quarter running to January 31st. This represented a 67 percent year-on-year increase in turnover for the GeForce branding, which was roughly 50 percent of the company's total revenue during that last quarter.

Gaming is Nvidia's bread and butter, but the gaming GPU story is complicated by the ebbs and flows of the cryptocurrency market. While last year crypto was still in the shadow of the enormous 2017/2018 run, the market began hitting all time highs again in December 2020 and there hasn't really been much in the way of a correction by March 2021. When the price of crypto is inflated it becomes more profitable to mine cryptocurrencies and it just so happens that gaming GPUs offer one of the best bang-for-buck propositions for startup miners.

The unpredictable cycles of digital currencies have a big impact on GPU availability as we saw clearly during the last run, but GPU manufacturers still haven't found a way to capitalise on crypto opportunities without snubbing its more reliable user-base of gamers.

Nvidia has given it another crack, by deliberately crippling the GeForce RTX 3060 GPU's crypto performance with software that halves the hash rate when mining Ethereum, and introducing a new range of dedicated cryptocurrency mining cards called Nvidia CMP.

> *"When the price of crypto is inflated it becomes more profitable to mine cryptocurrencies and it just so happens that gaming GPUs offer one of the best bang-for-buck propositions for startup miners."*

According to *APC*'s friends at *Tom's Hardware*, three of the four new CMP HX cards (the 30HX, 40HX and 50HX) would be based on the earlier Turing silicon architecture of the GTX 1660, the RTX 2070 and the RTX 2080 Ti, respectively. By using older silicon, the company can introduce more cards to the market without using the same machinery for this year's Ampere-based GPUs. One CMP card however, the 90HX, does seem to be based on the same silicon as the RTX 3080 GPUs, but because it won't be released until the next quarter, it's hypothesised that Nvidia will be using recycled defective dies that don't meet the GeForce gaming standard.

While these moves seem good on the surface, Nvidia's crypto throttle will only be turned on for Ethereum-based blockchains, which means Bitcoin, or any of the other altcoins that are based off it (there are many), can continue to mine unimpeded on the 3060 cards.

Linus Tech Tips was also keen to point out that driver software throttling has been circumvented pretty easily in the past, and that the global silicon shortage will mean production of new CMP HX graphics cards will impede supply of the new 30-series gaming cards, whether it's on the same architecture or not.

Linus also argued that the CMP XH GPUs won't ever work as gaming GPUs, so gamers will be stripped of the potential to wait for the next crypto bust to grab a bargain GPU if there's too many CMP HX cards produced.

We'll leave it to you to decide whether Nvidia's looking out for gamers or if it's just trying to placate them. ■

JOEL BURGESS
When not reviewing PCs for *APC* and writing our funny pages, Joel likes to ponder tech and how it's used.

A now-ancient OCZ U.2 SSD.

TWO BITS

It's time to rethink the M.2 form factor.

They're getting a little hot under the collar.

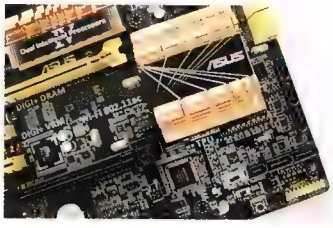
Don't get me wrong, I love the performance on offer from today's fast PCIe 4.0 NVMe drives. But, a couple of years back in this column I wrote about how I thought the M.2 form factor had very few pros and a lot of cons. Individual product reviews aren't the place to air those kinds of thoughts, but now, having tested a few high-end PCIe 4.0 drives, I feel the need to put the rant hat on once more, and tell you why I still believe that M.2 is a dud form factor.

M.2 drives are fiddly. The tiny screws are a pain and often drop into the darkest recesses of a case, never to be seen again. You often have to take off an acre of motherboard heatsink to access the slots, only to find the thermal pad is inadequate, missing or damaged from a previous install. They are often adjacent to a hot graphics card. So, do those large heatsinks cool? Or heat? Let's hope that chipset fans don't make a widespread return. You also have things like PCIe lane limitations. What happens if you want to add a second or third drive? What happens to other slots or ports then?

We're also seeing that PCIe 4.0 drives run hot. With a suboptimal installation, you may find they can throttle, negating a lot of the performance advantage they offer. What about their effect on ever-increasing motherboard prices? Do several M.2 slots add complexity and create difficulties? It's not easy to build a PCB with PCIe traces running every which way across the entire bottom half of a motherboard. There's a bunch of cons for starters.

Now ask, what do we need the M.2 connector for? It's fine for something like a Wi-Fi card, but someone decided that drives connected by a cable were a problem that needed to be solved, even though no one had a problem with it in the first place. Why didn't SATA Express or U.2 see adoption in the consumer space? Is it because of unsightly cables? Modern cases with cable management features mean cables are easily hidden away. I really can't think of a reason why a proper PCIe-based 2.5in standard didn't take off. You can hide the drives themselves out of sight and mind. Plug them in and you're good to go. Hot-plugging even. Daisy chaining could have become a thing to negate PCIe lane limitations. Manufacturers could use the 2.5-inch casing as a heatsink. Although it'd be expensive, a 16TB QLC 2.5in drive would be a trivial thing to manufacture. Good luck packing all that flash onto a 2280 drive.

Please! Give me U.2 or hypothetical SATA Express 2 or SATA 4 ports, and then some drives to connect to them. These connections are so much more convenient. When I transfer a lot of data the drive won't throttle. The drive can be stashed away out of sight and out of mind, and on top of that it will be a lot easier to access and swap out when I need to. Thinking about it, I might feel safer about my data's integrity too. If I lose one more tiny M.2 screw I will toss that motherboard out the window. Actually, no I won't, but I'll want to! ■



A motherboard with SATA Express connections (lower right).

CHRIS SZEWCZYK
A life-long PC tech enthusiast, Chris has worked acoss the industry in many areas as a product and technology expert.

Our collection of unicorn graphics cards: the RTX 30 series and RX 6000 series remain at near-mythical levels of availability.

TECH TALK

Hello GPU shortages, again

The toil of buying a new graphics card is set to continue.

Last year's deluge of graphics card launches felt like a good thing. Ampere brought new levels of performance from Nvidia, and AMD closed the gap with its RDNA2 GPUs. Everybody wanted one, and the result was that every GPU launch was accompanied by out-of-stock notifications. Six months on, things aren't much better.

It all started with COVID-19. While the impact on graphics cards might seem like a relatively small item in the grand scheme of things, the manufacturing plants that produce graphics cards – from the GPUs themselves to the memory chips, VRMs, capacitors, PCBs, and other components – were all affected to varying degrees. The problem is that our manufacturing supply chain doesn't deal well with delays, and it can take days if not weeks when restarting production lines to get everything running smoothly again.

Compound all of that with shipping delays. Across the globe, a large chunk of the shipping industry has been diverted to help with routing medical supplies, and now vaccines. So an industry already starved of supplies also now faces restricted shipping.

Finally, we have the unprecedented demand for PC upgrades. Billions were facing government-enforced lockdowns, millions lost jobs, schools were closed. The assumption at the time was that demand would drop. Instead, people working from home wanted better PCs, and many figured that escaping into their favourite games would be a good way to pass the time.

Compounding interest is a harsh mistress, and if all of the above wasn't bad enough, now we have the surging popularity (again) of cryptocurrencies like Bitcoin and Ethereum. December and January saw all-time highs for BTC and ETH, and many other crypto coins as well. Which means, on top of everything else, we're once again looking at miners trying to snap up cards for their own use.

How do AMD and Nvidia fix the problem? In a word: time. Wafer orders for GPUs placed with Samsung and TSMC typically take several months before the GPUs are ready for integration into graphics cards, and they're only one part of the product. Getting all the other components together and assembling them into the final parts takes time as well, and the general rule is that it takes around six months for a chip to go from a wafer start to retail graphics card sitting on a shelf. And that's the easy part.

JARRED WALTON
Jarred Walton has been a PC and gaming enthusiast for over 30 years.

The bigger problem now is capacity. The increased demand for computer parts and other technology devices has basically tapped out all of the state-of-the-art manufacturing facilities. TSMC can only do around 60,000 wafer starts per month without building more fabs, but building a fab is a multi-billion-dollar project that takes several years. The same goes for Samsung or any other company looking to add capacity.

Last year, the word from Nvidia was that increased supply of Ampere GPUs would start in February. More recently, Nvidia's CFO indicated that it could take several more months before supply starts to catch up to demand. AMD hasn't made any promises, but its prospects don't look any better. My extremely cloudy crystal ball suggests that this winter could perhaps be when last year's GPUs actually start sitting on shelves for more than a second.

PlayStation 5

If you break it down, will it still play?

We finally put down our PS5 long enough to do a proper teardown. We really want this thing to work again when we're done. We're not going to hold back, though. Here we go.

MAJOR TECH SPECS

- AMD custom 8-core / 16-thread 3.5GHz Zen 2 CPU
- AMD custom RDNA 2 GPU (2,230 MHz with 36 compute units)
- 6GB RAM, 128GB storage (256 and 512GB configs available)
- 16GB GDDR6 RAM
- 825GB of SSD storage (plus an M.2 SSD expansion slot)
- HDMI 2.1 connectivity, support for 8K video at 60Hz, or 4K at 120Hz

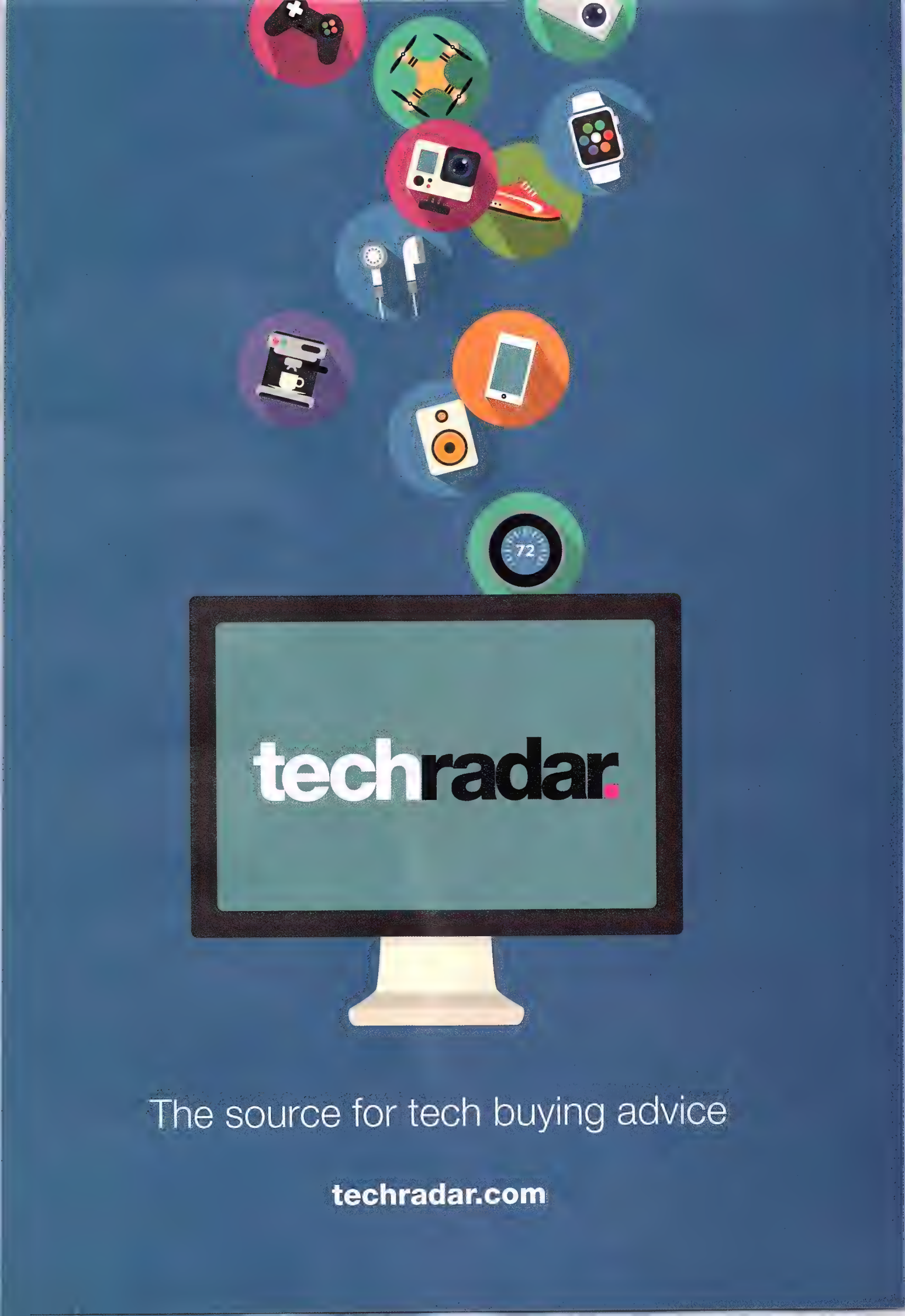
KEY FINDINGS

- The last fully fledged, whole-number PlayStation launch was back in 2013, so we're pretty excited. You may have heard that the PS5 is big. This thing towers over its predecessor – not to mention its competition. Around the back, the PS5 shows off its ports: two USB-A 3.0, LAN, HDMI 2.1, and two-pin power. Add those to the duo of USB ports on the front (one Type A, one Type C), and you've got a reasonably well-connected console.
- The opening procedure is actually quite human-friendly. Both white panels pop off with a gentle lift-and-slide motion – allowing immediate access to the M.2 SSD expansion slot, the fan, and… vacuumable dust ports. When it comes to easy maintenance of your console's cooling hardware, we're big fans. But to go any farther, we need a T8 Torx Security driver (why does your PS5's fan need security screws?). The M.2 storage expansion bay is very accessible. Remove one Phillips screw and a metal shield, and you're ready for upgrades. That's thoughtful, since the built-in storage is worryingly limited.
- As we remove the first half of the black plastic shell, we're greeted by the optical drive. The slender optical drive doesn't put up much of a fight coming out – which would be good for potential replacements, until you actually try a replacement. Underneath there's a heat pipe for cooling a row of VRMs, connected to a baby fin stack. Looks like we're seeing the back of the main board – all the serious cooling hardware is mounted down below. We may be approaching a point of no return, but let's un-mount the hardware and flip the board out.
- Here's a look at the silicon that powers the PS5: Sony Interactive Entertainment Inc./AMD CXD90060GG 8-Core CPU w/ GPU, Sony Interactive Entertainment Inc. CXD90062GG SSD Controller, SK Hynix H5AN4G8NBJR-UHC DDR4 SDRAM Memory – 512 MB, 6x (three per side) Kioxia/Toshiba Memory TH58LJT0T24BA4M BiCS flash memory (likely) and Micron MT61K512M32KPA-14:B 2 GB GDDR6 SGRAM.
- Underneath metal shield number two is a massive heatsink and the power supply. Since heat rises, it makes sense that this heatsink is designed to move heat upward through all those heat pipes. All the while, the heat radiating through the silver fin stacks is blown away by the fan.
- PlayStation 5 Repairability Score: 7 out of 10 (10 is easiest to repair).

Outer covers can be replaced without tools. Many components are modular, and disassembly is straightforward. Vacuumable dust ports makes de-dusting easier. The main storage is integrated to the motherboard, but expansion should be easy (once enabled by Sony) with off-the-shelf M.2 SSDs. The optical drive is a cinch to replace, but cannot be easily swapped. ■

Did somebody tell Sony that we love screws? Because this steel plate is secured with a ton of screws. Um, thanks!

It doesn't take a rocket scientist to pop open this next-gen console.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GADGETS

TECHY TOYS THAT MAY OR MAY NOT INSPIRE JOY

$10,999 | samsung.com

Samsung The Terrace

4K QLED outdoor TV now in 75in full-sun edition.

We've covered Samsung's water and dust resistant The Terrace outdoor TVs before, but there's a new bigger 75-inch model that's suitable for full sun situations that's worth mentioning. It gets the same 2,000nit brightness of its siblings, which is bright enough to compete with daytime background light, and has an anti-glare finish that cuts out bright reflections. Combine this with 4K quantum-dot technology and a HDR colour palette and you'll get an unparalleled outdoor viewing experience. It also includes a water resistant remote and all the smartphone mirroring and smart TV features you get on today's leading living room tellies.

$2,099 | store.DJI.com

DJI FPV Combo

Really put yourself in the driver's seat of your next drone.

DJI has been the master of the drone space for a while now, but it generally goes for the cinematography market, so we're intrigued to see the FPV Combo's slightly more racing focus. An integrated 4K 60fps camera with automatic horizon lock gimbal combined with DJI's onboard flight management system turns FPV flying from a challenging experience into something a novice can pick up. It even includes an additional remote that lets you use intuitive wand motion to control the drone. While this low latency system makes it easy to feel intimately connected to the device, it'll also capture smooth high resolution footage thanks to the inbuilt digital image stabilisation.

US$210 | radar.com

Ryidar LinkLens

Smart goggles that you might actually use.

There's plenty of Bluetooth headphones that make it possible to listen to music when on the slopes these days, but having a streamlined audio system built directly into your goggles is a pretty sweet deal if you ask us. Apart from being one less thing to worry about, the open-ear speakers allow you to enjoy music or talk on the phone without occluding the sound around you so you can hear what's going on at all times. It's also got simple left- or right-ear only toggles and full smart assistant passthrough, so you can get your smartphone to do things while you're on the go.

US $2,000 | store.segway.com

Segway Ninebot Gokart Pro

This Seg' is way cooler than anything we've seen before.

We were pretty impressed with Segway's first Ninebot Gokart, but after two years experience building mini race cars the company has released an 'completely reimagined' version. The new Ninebot Gokart Pro manages to get up to almost 40km/h and has a range of around 24km and manages to outperform 150cc petrol-powered carts on race tracks. There's an included speaker that can blast your favourite tunes or simulate anything from a single-cylinder to 12-cylinder engine noise, and the smartphone app allows you to adjust the level of drift assist programmed into your Gokart to suit your driving style and the conditions.

$17,795 | au.flightboard.com

Flightboard Series 2

Glide across the water with this electric surf board.

If you've always wanted to be cool like Mark Zuckerberg then you'll need to get your hands on a hydrofoil in the vein of the Flightboard Series 2. This device uses a propellor and submerged wing to provide lift and drive through the water while elevating the rider out of it to reduce drag. This allows you to get a serious amount of torque from the remote controlled propellor that will push you at up to 40km/h across the water. More than enough to catch waves or cut through a wake.

$129 | polar.com

Polar Verity Sense

A lightweight heart rate tracker you can take to the ends of the earth.

Polar's new optical heart rate sensor the Verity Sense promises more accurate exercise tracking without extra bulk. The ultra-lightweight 5g sensor contains six LED optical heart rate trackers and an accelerometer that can determine distance and pace. While most smartwatches and fitness bands have these capacities these days, Polar has designed Verity Sense to be able to fitted on a pair of goggles to minimise drag while swimming, and the battery will last up to 20 hours. 50m water resistance, 600 hours onboard data memory and Bluetooth or ANT+ connectivity means you'll be able to train anywhere.

REVIEWS

THE HOTTEST GEAR LABS TESTED

$3,099 | gigabyte.com

Aorus 15P

Gigabyte's keeping the new course on its gaming rigs, we're just hoping there's no icebergs on this full-steam-ahead approach.

Gigabyte has shifted the Aorus brand away from the ultra-premium gaming space into the high-end but better value arena, a trend clearly continuing in the Aorus 15p. Both new variations feature an Intel 10th generation Core i71087H CPU capable of boosting to 5GHz on all eight cores, and a fast 512GB PCIe SSD that hits 3,500/2,500MB per second read and write speeds. Then, depending on which model you choose, you'll either get 16GB of RAM and a new Nvidia RTX 3060 Max-P GPU for $2,799 or 32GB of RAM and a Nvidia RTX 3070 Max-P GPU for a total of $3,099.

While the Aorus 15p doesn't offer a configuration featuring the most powerful GTX 3080, we reckon this is a smart move this year, considering the wide performance range you'll get from the top shelf laptop GPU. Much like last year's units, the materials on the Aorus are less sophisticated than what we got on the original devices, but the all black design isn't particularly offensive either.

Even on the last device Aorus spent a bit of time customising the keyboard to ensure it was of the highest class, and while we have no complaints about the RGB keyboard this time around, there's also nothing to really get excited about.

Best result
On test

	Gigabyte Aero 17 HDR YC	Aorus 15P XC
PCMark 10 - Overall (score)	5,715	6,169
Max CPU Temperature (°C)	94	84
1080p movie playback (HH:MM)	04:08	04:39
HWBot x265 - 1080p (Avg fps)	44.552	43.084
3DMark Time Spy (score)	9,518	9,829
The Division 2 - 1080p Ultra (fps Av.)	85	87
CrystalDiskMark Read (MB/s)	3,404	3,267
CrystalDiskMark Write (MB/s)	3,035	2,543

SPECS
Windows 10 Home 64-bit; 15.6-inch 240Hz IPS display @ 1920x1080p; Intel Core i7-10870H CPU; 32GB RAM; Nvidia GeForce GTX 3070 Max-P GPU; 512GB PCIe SSD; 99Wh battery (4h35min 1080p movie playback); 357x244x27mm; 2.2kg.

Dash over to Gigabyte's website and you'll be met with the slogan "PERFORMANCE PERFORMANCE PERFORMANCE PERFORMANCE" on the 15P's page, which subtly indicates the focus of this laptop. While the Aorus was never really lacking in that department, it's good to know that this parameter at least should be up to scratch. In fact, put it up next to Gigabyte's own double-the-price Aero 17, with an RTX 2080 GPU, and the Aorus 15P actually beats it in *The Division 2*, *Metro: Exodus*, and *Sid Meier's: Civilization VI* by as much as 10 percent in 1080p Ultra benchmarking. We ran out of time to test the Aero 15P's capabilities at 4K resolutions but we suspect that's the only place you'll see devices with 3080's outpacing this unit.

This means the 15.6-inch 240Hz 1080p display is particularly suited to this high frame rate performer which can hit 129fps averages in F1 2020, which is more than enough to give you a competitive edge for enthusiast- or pro-level gamers at 1080p. While it doesn't have the HDR capabilities of some of its predecessors, the screen is still X-Rite Pantone-certified and factory calibrated to produce 72 percent NTSC (99 percent sRGB) which will look great in games and can be used for SDR colour editing.

Intel is yet to release an update to its performance range of laptop processors, so this unit uses an almost identical 10th Gen CPU to the one in last year's Aorus 17G. These are still some of the highest performing laptop chips, so you won't feel hard done by in demanding work tasks, but it's been a while since there were absolutely no CPU performance improvements between generations.

Storage was a little lighter than we like to see on gaming laptops at just 512GB, but battery life was ok, at least by portable gaming standards, at around four and a half hours in both battery benchmarks.

JOEL BURGESS

A decent step-up gaming rig that is overpriced and short on storage.

★★★☆☆

$700 | www.synology.com

Synology HAT5300 12TB NAS hard drive

The NAS maker starts selling its own NAS hard drives. But, should you be buying them?

Synology has been synonymous with NAS for some twenty years but it's never made the drives that actually go inside its devices. Now, it's selling branded, NAS-optimised hard disks and locking some of its NAS buyers into using them. What's going on?

First up it's worth examining the reasons for buying a dedicated NAS drive. The firmware is optimised for NAS workloads with error correction features helping avoid failures. Physical hardware vibration control is often included, they're quieter, they're rated to significantly higher failure tolerances, consume less power and come with longer warranties.

Such technology naturally takes many years to perfect and so Synology is using third-party drives – from Toshiba – and adding its own firmware and branding. This firmware also communicates directly with Synology's DSM operating system and can be upgraded/updated accordingly.

Plonking old hard drives in a NAS can generate noisy vibrations that affect performance, potentially shorten the life of every component inside the NAS and threaten data integrity. To this end, Synology has taken the nuclear option and is not just banning non-NAS drives from working in its forthcoming mid-range (and above) devices, but it will now require third-party specialist NAS-drives to be Synology certified. It's done this, "In order to ensure consistent and reliable operation of our solutions." This won't be retroactively applied to existing NAS boxes but Synology adds, "Installing non-validated drives will result in Storage Pools being unable to be created [and] SSD cache cannot be created using non validated drives." Note: if you use a Synology Expansion Unit (to add extra drives) then it will inherit whatever firmware locks the parent NAS has.

What's rather irksome is that while Synology's new drives are available in 8, 12 and 16TB flavours, the maximum capacity of current, certified, third-party drives is just 4TB! While we expect the likes of high-capacity Seagate NAS drives to soon be certified, only time will tell what certification requirements will do to pricing and how this will affect the market.

We've suffered from noisy Synology NAS boxes ourselves and using specialist drives certainly makes a difference. Installing two of Synology's 12TB drives in a four-bay model saw annoying vibration noises caused by old predecessors transform the noise from an irritating, 40-60dB fluctuating drone (the noise equivalents of whisper-quiet and a standard conversation) to a steady 40dB when idling. The inherent pops and whirrs peaked at 50-60dB but, unless it's constantly under load in a quiet home or office, it's not distracting.

We ran some Windows-based tests to establish baseline performance: the formatted capacity of a 12TB drive is 10.9TB and CrystalDiskMark shows they're capable of impressive (for a mechanical drive) 258MB/s read and write speeds. This, especially in a RAID, will easily mitigate bottlenecks in most home and SMB environments.

Toshiba's parent 12TB drives aren't widely available in Australia, but Seagate's comparable Iron Wolf rival costs around $500. In the face of this Synology's price tag of $700 is unappealing. But, for forthcoming mid-to-high-end Synology customers, it might soon be the only option.

NICK ROSS

SPECS
3.5-inch, SATA III, 7,200rpm, mechanical hard drive; 256MB buffer; 2.5 million-hour MTTF (mean time to failure) rating; 550TB/year workload support rating; Automatic firmware updates with DSM OS; 5-year warranty; weight 720g.

Too expensive and too-little evidence to justify locking out similarly specified rivals

★★☆☆☆

$699 | xpg.com

Adata XPG Gammix S70 Lite 2TB

Hitting the limits of PCIe 4.0.

PCIe 4.0 SSDs are coming thick and fast. With Intel's upcoming 11th Gen CPUs finally including support, PCIe 3.0 SSDs will rapidly fall by the wayside. Adata mightn't have the manufacturing capabilities of the likes of Samsung or Western Digital, but that doesn't mean the company isn't a serious player in the memory and SSD business. We've always loved the great blend of performance and affordable pricing. Can the 2TB Adata XPG Gammix S70 impress us once more?

The S70 is a standard form factor M.2 2280 (80mm length) NVMe drive that makes use of a PCIe 4.0 x4 interface. Its attention grabbing headline is its incredible sequential read and write speeds. At 7,400MB/s and 6,400MB/s, it's the fastest rated drive we've seen to date. It makes use of Micron-sourced 96-Layer TLC NAND. The S70 includes a 2GB DRAM buffer and it can allocate up to around 30 percent of its capacity as an SLC cache. This would mean around 600GB for the 2TB drive. Unless you're doing some truly mega writes, that will be more than enough to keep the drive performing at its best for sustained durations. Other key features include AES 256-bit encryption and a very impressive 1,480TBW endurance rating. The 1TB S70 has a 740TBW rating which is better than competitors including the Samsung 980 Pro and WD SN850.

The S70 uses an Innogrit Rainer controller, one that we haven't seen utilised to date. This eight-channel controller allows the drive to reach the limits of a PCIe 4.0x 4 connection, a stunning achievement, though we're at the stage where sequential performance of 6 or 7 GB/s is rarely utilised in a desktop PC. It comes equipped with a chunky heatsink. Adata says it should not be removed. If this doesn't suit your build, a heatsink-less S70 is due to arrive on the market in March. The S70 needs some kind of cooling though, as in our testing the drive hit 70C, even with the heatsink attached and decent airflow.

Just look at those sequential read and write numbers. They put the WD and Samsung to shame. But, while sequential performance looks good on a spec sheet, it isn't what truly makes an SSD fast. It's the random performance, IOPS and latency. This is where the S70 falls a little behind, and its even behind the much cheaper S50 Lite in some cases. The write performance is strong though, and the DRAM buffer and SLC cache really assist with write performance. So that, along with the excellent endurance rating, makes this drive a great choice if you frequently move a lot of files around, such as you might do when video editing.

The Gammix XPG S70 is very fast drive if you can make use of its strengths. while its sequential performance is very good, it's not a one size fits all drive. If you're a gamer there are better and more affordable options. Right now it's too expensive compared to many other 2TB NVMe drives and particularly Adata's own S50 Lite. The way the market is though, we'd expect pricing to stabilise. For now, it's tough to recommend the S70 unless you need a drive for heavy sustained use. In that case, its great, but for a more casual user or gamer, there are better options.
CHRIS SZEWCZYK

SPECS
Adata XPG Gammix S70 2TB NVMe M.2 SSD; PCIe 4.0 x4; Innogrit Rainer Controller; Micron 96L TLC NAND; 7,400 MB/s sustained read, 6,400 MB/s sustained write, 650K/740K read/write IOPS; 1480 TBW endurance; five year warranty.

The S70 is blazing fast, but its random read performance isn't as exceptional as its stunning sequential performance.
★★★½☆

APC LABS BENCHMARKS

Indicates best result

	Crystal Disk Mark		Anvil Storage Utilities				Internal File Copy
	Sequential Read MB/s	Sequential Write MB/s	4K Random Read MB/s		4K Random Write MB/s		30GB of mixed file sizes
			Queue Depth 1	Queue Depth 4	Queue Depth 1	Queue Depth 4	Time (seconds)
Samsung 980 Pro 500GB	6,855	4,937	69.17	76.19	202.6	157.92	24
Gigabyte Aorus 1TB	4,971	4,257	55.62	53.17	183.77	176.03	29
Adata Gammix S70 2TB	7,420	6,717	63.41	60.46	241.76	165.26	26
Adata Gammix S50 2TB	3,886	3,245	68.56	65.67	215.21	171.19	32
Western Digital Black SN850 1TB	7,026	5,218	80.66	70.16	240.90	179.31	27

$499 | xpg.com

Adata XPG Gammix S50 Lite 2TB

A PCIe 4.0 drive at PCIe 3.0 prices.

PCIe 4.0 SSD's are on track to take over the performance NVMe SSD market. It will take some time, but soon PCIe 4.0 drives will find their way into all but basic SATA-equipped systems. That trend will be accelerated by the likes of the Adata XPG Gammix S50 Lite. The name might be a mouthful but at $499 for the 2TB version, it offers a lot of value. In fact, it's already competitive in both performance and price with PCIe 3.0 drives; at the time of writing it was some $200 cheaper than Adata's own 2TB S70.

The XPG Gammix S50 Lite is a standard form factor 2280 (80mm length) M.2 drive that connects via a PCIe 4.0 x4 interface. It's designed to be a budget-oriented drive but with sustained read and write speed ratings of 3,900 and 3,200 MB/s respectively, its already as good as the fastest PCIe 3.0 drives. Its random performance and IOPS are also competitive with quality PCIe 3.0 drives. The S50 Lite makes use of quality Micron 96-Layer TLC NAND. Unlike cheaper drives, the 2TB S50 Lite includes a 1GB DRAM buffer and 300GB of SLC caching. This helps the drive maintain its performance under a heavy load for far longer compared to DRAM-less budget drives. It also features AES 256-bit encryption and a very impressive 1,480TBW endurance rating (or 740TBW for the 1TB drive). The much more expensive WD SN850 doesn't have that, and it has a lower endurance rating too. So, while the S50 Lite might be an affordable PCIe 4.0 SSD, it packs in features that belie its affordable price. It looks nice too with its classy heatsink, and it also doesn't run as hot as the premium drives.

The S50 Lite uses the new Silicon Motion SM2267EN controller. This affordable PCIe 4.0 controller is key to the performance of the drive, as PCIe 4.0 support allows this 4-channel controller to match the performance of more complex and expensive 8-channel PCIe 3.0 controllers. It seems like the S50 Lite ticks all the boxes. So how does it perform?

Sequential read and write performance is at the low end for a PCIe 4.0 drive but that tends to be an overrated spec for desktop users. It's not all that often that a regular user will need to shift around hundreds of gigabytes of data, where you will exhaust the cache. In terms of random read performance, the S50 Lite actually managed to steal the thunder of the much more expensive S70, though it can't match its write performance. It also ran much cooler than other PCIe 4.0 drives without having to resort to a big chunky heatsink. We saw a peak temperature of 62c.

The Gammix XPG S50 Lite is one of the best value NVME SSDs on the market. There's still a price premium attached to PCIe 4.0 drives, but that's likely to change as demand picks up, especially as Intel upgraders enter the market. At $499 for the 2TB version, considering its feature set, decent read performance and excellent endurance rating, it's one of our favourite SSDs and comes highly recommended.

CHRIS SZEWCZYK

SPECS
Adata XPG Gammix S50 Lite 2TB NVMe M.2 SSD; PCIe 4.0 x4 interface; Silicon Motion SM2267EN Controller; Micron 96L TLC NAND; 3,900MB/s sustained read, 3,200MB/s sustained write, 490K/540K read/write IOPS; 1,480 TBW endurance; five year warranty.

The Adata S50 Lite offers great features and value. It will surely find its way into many new PCIe 4.0 systems.

★★★★½

APC LABS BENCHMARKS

Indicates best result

	Crystal Disk Mark		Anvil Storage Utilities				Internal File Copy
	Sequential Read MB/s	Sequential Write MB/s	4K Random Read MB/s		4K Random Write MB/s		30GB of mixed file sizes
			Queue Depth 1	Queue Depth 4	Queue Depth 1	Queue Depth 4	Time (seconds)
Samsung 980 Pro 500GB	6,855	4,937	84.37	78.14	202.6	157.92	34
Gigabyte Aorus 1TB	4,971	4,257	55.62	53.17	183.77	176.03	29
Adata Gammix S70 2TB	7,420	6,717	63.41	60.46	241.76	165.26	26
Adata Gammix S50 2TB	3,886	3,245	68.56	65.67	215.21	171.19	32
Western Digital Black SN850 1TB	7,026	5,218	80.66	70.16	240.90	179.31	27

$419 | westerndigital.com

Western Digital Black SN850 1TB

Samsung has some serious competition.

It seems like it was just yesterday that we were wondering when traditional HDD manufacturers like Western Digital were going to enter the SSD market. And enter it did. After the acquisition of SanDisk, WD became one of undisputed leaders in the SSD space. Straight up, the SN850 is one of the fastest SSDs we've ever tested.

Western Digital is one of a handful of manufacturers that has the capability to design and manufacture its SSDs in-house. This means it doesn't have to rely on third-party manufacturers or generic firmware. We hope this leads to cost advantages that can be passed on to the consumer, though at the time of writing, the 1TB model we're reviewing is priced at over $400. That's too expensive, though we're sure that will change once the launch phase passes.

The WD SN850 is a standard form factor M.2 2280 (80mm length) NVMe drive that makes use of the now widely adopted PCIe 4.0 x4 interface. It uses WD's own BiCS (Bit Cost Scaling) 96-layer 3D TLC NAND flash memory. There aren't many public details on the WD Black G2 controller the drive uses, though there is a 1GB DRAM buffer and SLC caching that both help to maintain top performance. Additional features include S.M.A.R.T. monitoring, trim and garbage collection. Curiously there's no AES drive encryption, something we noted with the SN750. The five-year warranty and 600TBW endurance rating of the SN750 are carried over to the SN850.

WD deserves credit for its Dashboard SSD management software, particularly the interface. The usual things like monitoring, secure erases and firmware updating are all present. You can also download a copy of the Acronis True Image disk cloning software from the WD website.

We expected the SN850 to perform to a very high level, and we weren't disappointed. Its random write performance is the best we've seen from any SSD. This means it's a great option for users who frequently write files to the drive, particularly content creators. Its read performance is also good, but its low queue depth performance and IOPS are a bit behind the Samsung 980 Pro. This is what gives an SSD its 'snappiness' though at these levels it's not going to be noticeable. It must be noted that M.2 PCIe 4.0 drives can get very hot when pushed hard for a sustained period of time. The SN850 doesn't come with a heatsink, so you'll be best served by putting it under a motherboard heatsink. If not, you'll need good airflow. We saw a peak of 68c in an open testbed environment, which means a closed, cramped case could see temperatures a lot higher than that.

There's no doubt that the SN850 is a very fast drive. Its excellent write performance will appeal to content creators and users that frequently move large amounts of data around. It's no slouch anywhere else either. The problem is that the similarly excellent Samsung 980 Pro can be found for a much cheaper price. As is almost always the case with a new release SSD, pricing usually decreases over the life of the SKU. If and when that happens, the WD SN850 is sure to take its place alongside the 980 Pro. That alone is a serious achievement.

CHRIS SZEWCZYK

SPECS
Western Digital Black SN850 1TB NVMe M.2 SSD; PCI Express 4.0 x4; WD Black G2 Controller; WD BiCS4 96-Layer TLC NAND; 7,000 MB/s sustained read, 5,300 MB/s sustained write, 1M/720K read/write IOPS; 600 TBW endurance; five year warranty.

This WD is very fast indeed, but for now the equally impressive Samsung 980 Pro offers much better value.

★★★★☆

APC LABS BENCHMARKS

Indicates best result

	Crystal Disk Mark		Anvil Storage Utilities				Internal File Copy
	Sequential Read MB/s	Sequential Write MB/s	4K Random Read MB/s		4K Random Write MB/s		30GB of mixed file sizes
			Queue Depth 1	Queue Depth 4	Queue Depth 1	Queue Depth 4	Time (seconds)
Samsung 980 Pro 500GB	6,855	4,937	84.27	76.14	202.6	157.92	24
Gigabyte Aorus 1TB	4,971	4,257	55.62	53.17	183.77	176.03	29
Adata Gammix S70 2TB	7,420	6,717	63.41	60.46	241.76	165.26	26
Adata Gammix S50 2TB	3,886	3,245	68.56	65.67	215.21	171.19	32
Western Digital Black SN850 1TB	7,026	5,218	80.66	70.16	240.90	179.31	27

$899 | ben1.com

BenQ Zowie XL2546K

The latest in old-school, cutting-edge, ancient, gaming monitor tech designed for modern-day eSports professionals.

In a world where gaming monitors are competing to offer the most immersive game reproduction, best viewing angles, biggest curved screens, brightest colours and most jaw-dropping HDR contrast – all in an effort to make the latest games look pretty – BenQ's latest Zowie XL2546K looks on from the wings with a pitiful disgust. This is a monitor that has been designed, first and foremost, to play the eight-year-old *CS:GO* FPS video game (and its derivatives) at a world championship-winning level.

This 24.5-inch, 1080p monitor, with a matte, anti-glare coating, doesn't just use the ancient TN panel technology to reduce the image ghosting and blur that's inherent in LCD panels, it also has a 240Hz refresh rate to add an extra layer of motion smoothness and further reduce ghosting and blur. These features are not unique, but BenQ's skunkworks Zowie team has layered its proprietary "DyAc+" technology on top of all this to further reduce ghosting and blur to the point where even spray firing, recoil control and screen-shake caused by explosions can leave your crosshair and enemies displayed in sharp relief. BenQ itself says that some of the image enhancements offer a one percent improvement that won't be noticeable to everyone, but international *CS:GO* tournaments have been decided by smaller margins.

It's not only the panel technology that has been designed for pro gamers, but the ergonomics too. The screen doesn't just offer generous adjustments in terms of tilt, height and swivel; all of these increments are measurable with embossed notches so you can sit-down and adjust everything to near-millimetre accuracy without having to eyeball your setup. This is important at tournaments where competitors share screens and is useful for gamers to instantly set up their monitor after transporting it to a LAN. To this end, there's even a carry handle at the top and a PVC screen-protector included in the box. Also included are side-mounted sightscreens to reduce glare and hide distractions. There's also a fold-down hook at the rear to hang your headset on.

The monitor's bezel isn't particularly thin at 13mm so it's not great for tiling. The screen itself is held firmly by the small-footprint base.

SPECS
24.5-inch, matte, 1,080 x 1,920, flat-screen, 240Hz LCD with TN panel. 320 nit brightness, 1000:1 contrast. DyAc+ anti ghosting technology. DisplayPort 1.2, 3 x HDMI 2.0, 3.5mm audio jack. Tilt -5o/+23o, Swivel -45o/+45o, 90o rotate, 15.5cm height adjustment. Wired remote. 521-366 x 571 x 200 mm, 6.2kg.

The OSD can be operated by a mini-joystick at the rear or an 'S-Switch' wired remote that makes settings simple to access. Settings for different games or users can be saved on the monitor and shared using BenQ's Setting to Share app – handy considering all the image adjustments. The adjustments themselves are designed to butcher colour accuracy and contrast to make it easier to identify enemies hiding in shadows and highlights; this, together with the old-school TN panel technology (with its poor viewing angles), means it's not great for graphical work or watching movies. It does however present a perfectly usable Windows Desktop for office work.

If competitive FPS gaming is your profession or your passion, then the BenQ Zowie XL2546K can be regarded as a professional tool that's reasonable value at $899. However, if you want games to look amazing and immersive, look elsewhere.

NICK ROSS

When it comes to the old-school monitor technology that competitive FPS gamers like, this represents the pinnacle of current evolution.

★★★★★

$899 | tp-link.com/au

TP-Link Deco X90 Whole Home Mesh Wi-Fi System

TP-Link adjusts its business model. But is it a good idea?

Against the backdrop of the mainstream Wi-Fi router and mesh markets, a new category has been developing: that of the powerful, two-node system which offers wired-like performance from one end of a premise to the other. The Deco X90 represents TP-Link's first foray into this category but how will it fare in the face of impressive,rival offerings from Asus and Netgear?

The two nodes are large, stylised cylinders that aren't unobtrusive. Each sports only two ports: a Gigabit LAN and a 2.5Gbps WAN/LAN which will feel limiting to some buyers.

Initial setup is simple via TP-Link's Deco phone app. It shows which devices are connected and the bandwidth they're using. You can re-label them, assign them to users and even blacklist them. Other settings include Guest Network, IP specification and Port Forwarding. Well-laid-out parental controls can assign access times, bedtimes, blocked websites and even content filters – but you should never trust the latter.

There are also optional extras that come courtesy of TP-Link's new Avira-based HomeShield Pro subscription service. It costs $9 per month or $93 per year ($150 per year with five, full Avira antivirus licences). It provides network intrusion prevention and IoT protection, plus enhanced child protection features (including the should-be-free Pause Internet functionality) in addition to internet time limits for different users and monthly reporting. Accessing QoS settings also costs money. It won't break the bank, but charging money for normal features earns TP-Link disapproving looks from us.

Under a Friends of Deco tab there are controls for IFTTT and Alexa smart home automations although, disappointingly, IFTTT support is soon to be dropped in favour of a proprietary TP-Link system. Google Assistant is absent.

As for performance, we expected great things with both nodes offering tri-band, AX6600 Wi-Fi 6 speeds. We positioned one on the ground floor by our modem and Synology 1019+ NAS box and the othert wo floors up by our main PC. We then downloaded large movie files from the NAS to our Dell XPS 15 OLED laptop. Up close it managed a fastest-ever 841Mbps! One floor up it fell to 393.5Mbps, which is still blisteringly fast. On the top floor, next to the node, however, performance collapsed to 158Mbps, which is good for a regular mesh system, but poor for a top-of-the-range Wi-Fi 6 router. Moving the node down one floor boosted the speed to an impressive 360Mbps but doing this transformed it into a regular mesh rather than a wireless way of providing a wired-like connection to a distant PC.

Ultimately, it's faster at short range than Netgear's impressive Orbi rival; however, that's ludicrously expensive at $1,399 and comes with additional, expensive, premium features. If you need the blistering short-range speed, can make use of the 2.5Gbps port and don't mind paying $9 per month for some basic features, then this $899 Deco can't be beat. However, the Asus Zen XT8 can now be had for $799 and offers similar features, without subscription, plus more-consistent performance at distance. Consequently, we recommend the Asus.

NICK ROSS

SPECS

Speed: Tri-band AX6600Mbps; Two nodes; Connectivity: 1x Gigabit LAN, 1 x 2.5Gbps LAN/WAN per node; Features: WPA3; Parental controls; Port Forwarding; Alexa compatible.

Potentially very fast indeed, but questionable premium features and long-range performance dent the value proposition.

★★★★☆

$366 | tendacn.com/au

Tenda Nova MW12 Whole Home Mesh Wi-Fi System

What's the better buy? The latest, expandable, last-gen tech or the expensive current-generation?

A year ago, we reviewed our first Tenda Wi-Fi product and were impressed with how easy it was to get up and running. At that point Tenda was an established brand in China but only really known on these shores for being sold in OfficeWorks. Now, it's more widely available and is offering this quasi-premium, three-node, last-gen Wi-Fi mesh pack for a not-insubstantial $366. In a mature, mesh market is that good value?

Each Nova node is a white, 10cm cube with a subtle cross-weave pattern on the sides that will fit discreetly into most homes. Each has three Gigabit Ethernet ports (one doubles as WAN for plugging directly into your modem). A small LED light on the top glows green when operational or orange when there's an issue.

Setup via phone was simple and all three nodes automatically detected each other just by turning them on. The app shows you which devices are connected and allows you to add descriptive labels. It offers access to settings including Guest Network, QoS (albeit for games and web browsing only) and some excellent parental controls which offer a wide range of incremental limits per device or group of devices. Also included are Port Forwarding controls and the ability to specify LAN IP addresses – rare for an app. Plus, a nifty Smart Assistant feature can force connectivity to the 2.4GHz band for 30 minutes while you attach any smart devices to the network.

The nodes promise AC2100(Mbps) speeds which, on paper, isn't too fast, but few superior mesh systems touch their potential. It also operates across three bands – 2.4GHz (300Mbps) and two 5GHz (867Mbps) with one of the latter being reserved for backhaul between nodes.

To see how it performed in the real world, we transferred large video files from a node connected to a Synology DS1019+ NAS (on the ground-floor of a three-storey Sydney Town House) to a Dell XPS 15 OLED laptop. We did this next to it and then on each subsequent floor. On the ground floor, it scored a very impressive 414.5Mbps, which is essentially 98Mbps faster than any mesh we've seen before. One floor above it dropped to 207.5Mbps, which, despite the decline, is also the best mesh score we've seen. On the top floor it scored 108Mbps, which is only bettered by TP-Link's Deco AX mesh – but not by much. Together, makes it the best all-round performing mesh we've seen. You can further expand coverage (and performance) by adding any model from Tenda Nova's broad node range.

SPECS
Speed: Dual-band AC 2,100Mbps; Three node; Connectivity: 3x Gigabit Ethernet per node; Features: Parental controls, QoS, Port Forwarding, Alexa compatible.

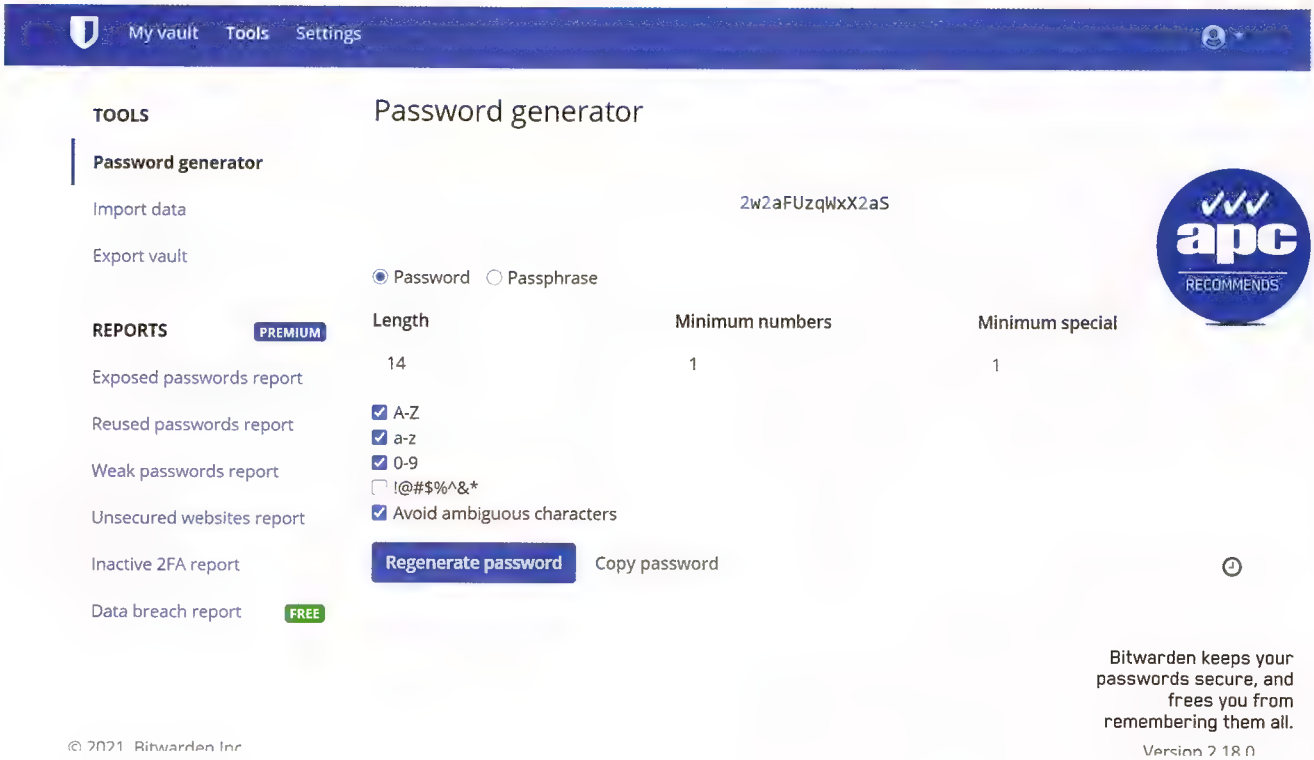
A top Wi-Fi 6 router will usually beat any mesh system, but most cost a great deal more than this. A mesh can also be more flexible than a single router, which can still struggle at distance if the construction of large premises are not conducive to Wi-Fi.

$366 is not cheap but it costs significantly less than many Wi-Fi 6 systems and yet can rival their performance at distance. If a single router doesn't suit your premises (or budget), this makes a great choice.

NICK ROSS

Fast, well-featured, easy-to-use with good, reliable coverage – everything you could want from Wi-Fi.

★★★★★



Bitwarden needs (for desktop app): CPU: 64bit dual-core RAM: 4GB | Free for personal use | bitwarden.com
LastPass runs on any PC that can run a supported browser | Free for personal use | lastpass.com

Bitwarden vs LastPass

The winner takes it all (and hides it) in the battle of the password managers.

Password managers are, we think, generally a good thing. Remembering adsofpjdp is one thing, but also committing 4256p4m2glm! and paLsdKfnk26& to memory is quite another. Keeping your passwords strong and changing them regularly is important these days, when you can check on a website whether or not you've been "pwned," and Chrome harasses you with your unfeasibly large number of compromised passwords.

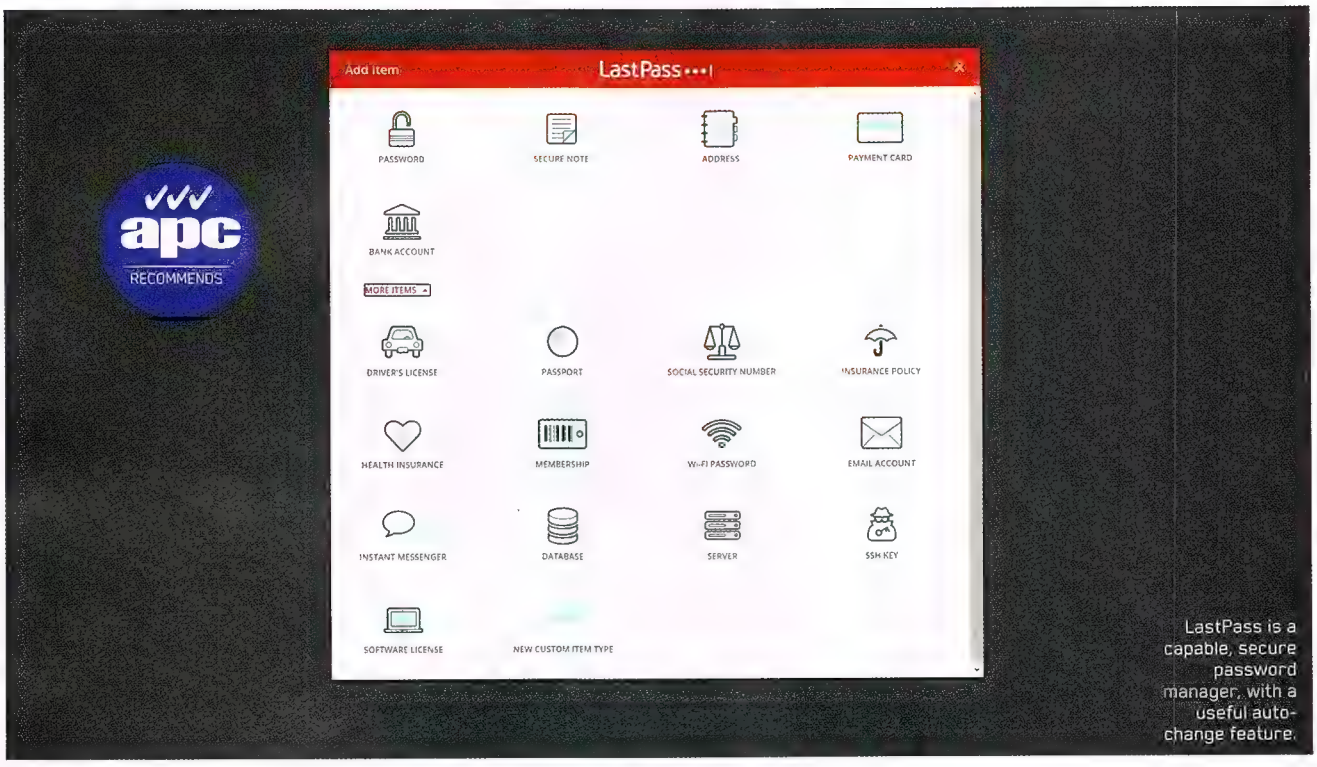
Web browsers, the front line in the war between password and jailbird, have been able to remember your passwords for a while now, and can generate strong passwords that you'll never be expected to remember. This is fine until you try to log in on a different system, or using your cell phone, and have to dig in the browser settings to view the password that it recorded for you.

There's another benefit of password managers: they tend to come backed with some sort of internet security suite or browser plugin. They also make it easy to manage your passwords, syncing across devices, generating new ones, and hiding everything behind a master password – which is the only one you need to remember. You can also use them to hide encrypted notes, too.

Of course, the downside of this is that they're massive targets for password thieves. Once they've compromised your master password, your entire digital life is laid open. It's worth, therefore, making that master password as complex as you can possibly cope with, changing it regularly, and never reusing passwords. There are also services, such as some banks, that don't support their use, and if you're caught with your banking details in one you may not get a refund if you're a victim of cybercrime.

Two of the market leaders in password-management software are LastPass and Bitwarden. Both are available for free, though they maintain premium subscription tiers if you need the additional features they can bring. The free apps, however, contain all the functionality you'll need as a one-person user, and only become limiting if you want to roll them out across entire organisations. You can store an unlimited number of passwords in both, and sync them across devices. They both generate random passwords when you sign up for a new service or want to change an existing password, and you can use them to encrypt information, such as bank details or credit card numbers.

Bitwarden is open source, which means it has faced external scrutiny from security experts, while LastPass is not. This doesn't mean there's anything wrong with LastPass's security, of course – it takes part in security audits – and neither app has reported a full data breach, though LastPass has been the target of some minor ones. LastPass offers a hint for your master password, which can save you if you've forgotten it. Bitwarden does not. Both apps offer plugins for major browsers - Chrome, Edge, Firefox, Opera, and Safari. Bitwarden goes one further and plugs into the, ahem, "privacy-focused" browser Tor, while LastPass works nicely with Internet Explorer. These plugins can be used to auto-fill identity



LastPass is a capable, secure password manager, with a useful auto-change feature.

fields within webpages, as well as manage your password database via the web interface.

Both services also come with desktop apps, although it's notable that Bitwarden's doesn't support two-factor authentication, and doesn't have the random-password generator or password-sharing abilities of the LastPass app. Both services use separate authenticator apps, however.

The award for user-friendliness has to go to LastPass, as its app and web interface are virtually identical, meaning you only have to learn how to use it once. Both managers use AES-256 – the only public security standard approved by the NSA – against which there is no known practical attack strategy that doesn't use a side-channel or some additional knowledge of the key.

Setting the apps up is a simple process. If you've got passwords stored somewhere, such as in Chrome, then they will import them for you. LastPass's Security Challenge feature regularly reminds you to change passwords that are overdue or weak, and there's an auto-change feature that can rattle through multiple password updates quickly – an extremely popular feature with users. LastPass also has recovery options if you lose your master password, sending one-time passwords to trusted email addresses. Bitwarden doesn't offer this – any passwords you store on its servers are accessible to you alone through the master password, so if you lose it or it becomes compromised, then you'll need to rebuild your entire password database.

Bitwarden has one feature you won't find in many other places: your password vault doesn't have to be stored on its servers. This is likely to be of more interest to corporate users (it's only available through the Enterprise subscription tier), but the ability to keep your passwords under your control on your own server can be an attractive feature. Both apps offer secure password-sharing between two users as part of their free tier, which scales up through their Premium and Enterprise tiers, and both offer a small amount of encrypted file storage too, as long as you're a subscriber.

It's worth pointing out again that both apps have a free tier, so it's perfectly possible to download them both, get them set up, and choose which one suits you best with no cost other than a little bit of your time. We're big fans of Bitwarden, but using either app is still better than using neither and trying to remember all your passwords, which inevitably leads to reused, weak passwords, or other security flaws. Password managers are also more secure and flexible than getting your browser to remember them.

Pricing is very close, with LastPass's tiers being slightly more expensive each month by a dollar or so. You may find, though, that you get more for your money with LastPass if you're going to go for one of the business-oriented tiers.

Either way, a password manager is a valuable addition to your enterprise, and anyone who uses passwords online can benefit from one. These apps are so similar that it will come down to which has a feature you like, or just personal preference as to which one you ultimately choose.
IAN EVENDEN

BITWARDEN
Open source and externally audited, though lags behind LastPass for several features.
★★★★☆

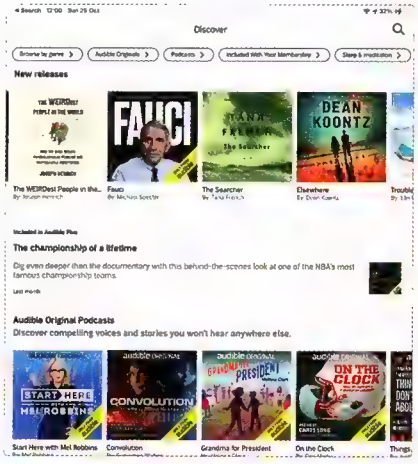
LASTPASS
Highly secure; available on all devices. Has had brushes with data loss in the past.
★★★★☆

6 apps for book lovers

Find more things to read, in more ways, and more people to discuss them with.

Thanks to COVID, we're all spending more nights at home, and that's been truer than ever for the end of 2020 and the beginning of 2021. Still, for bookworms at least that means even more time for settling down and escaping with a good book. Here, we've chosen some apps to help you get the most out of your literary habits, from finding new books to discussing them with a like-minded community.

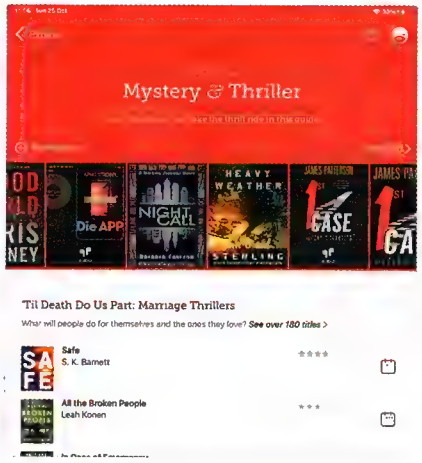
You'll notice that we haven't chosen Apple Books or Amazon Kindle here – it seems like a waste of space since these are already the go-to ebook store/reading apps. In this selection, we're looking at the less well-known options, giving book lovers new options and ideas for how to engage with one of the oldest and most comforting pastimes. These apps will help you discover new reads and share your recommendations.



Audible: Audiobooks & Podcasts

NEEDS iOS 13 or later | $16.45 a month

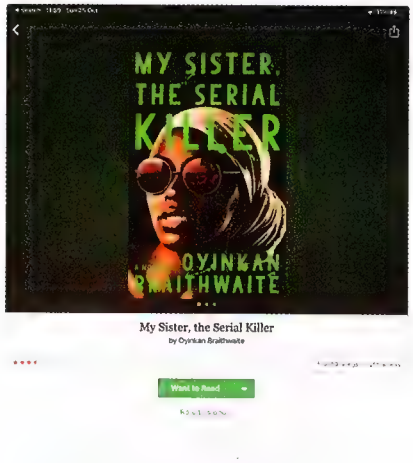
Okay, this might also be pretty well known, but if you haven't tried audiobooks yet, this is arguably the place to start. Pay monthly and you get credit for one audiobook purchase each month, plus extra free books and discounts. Your progress in books is synced across devices, and you can try samples. There's a free 30-day trial if you'd like to try it.



Libby, by OverDrive

NEEDS iOS 9 or later | FREE

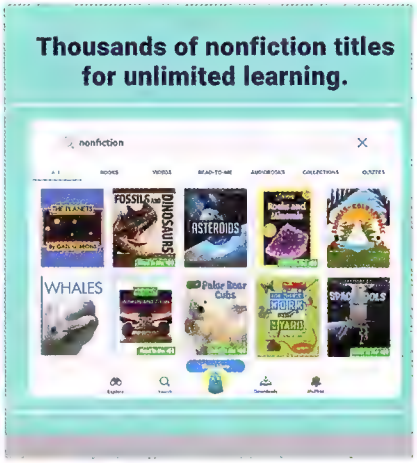
Did you know you can borrow ebooks from your library? Use your library card to download ebooks, then digitally return them. You can even use the app to send ebooks to a Kindle device. There are magazines and comics, and tools such as adding notes or bookmarks and searching text. Listed libraries are mainly in large city areas but we hope more will be added in time.



Goodreads: Book Reviews

NEEDS iOS 12 or later | FREE

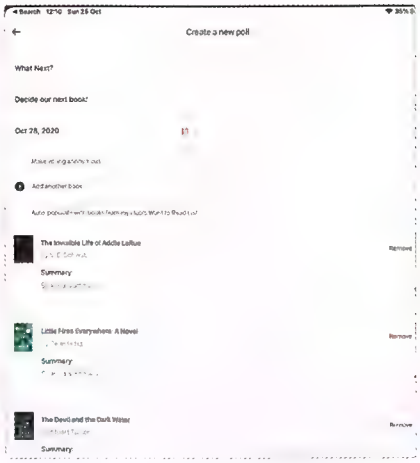
Want to keep a record of what you've read and what you thought of it? Goodreads is a book review tool where you can keep a book journal, share your thoughts with others, and see the opinions of others to help you decide what to read next. You can also engage with the community to discuss books and set reading targets with your friends.



Epic – Kids' Books & Reading

NEEDS iOS 10.3 or later | US$7.99 a month

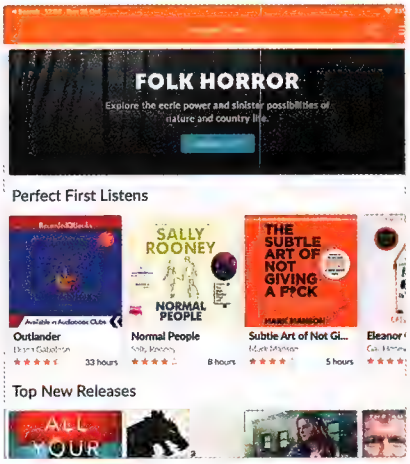
This all-you-can-read app is perfect for children who love books. It has over 40,000 fiction and non-fiction titles for youngsters, aimed at different ages. The US$7.99 monthly fee includes profiles for four children, and the app recommends things for each child based on previously enjoyed books. It will also keep a reading log, and there are audiobooks too!



Bookclubz: Book Club Organizer

NEEDS iOS 10 or later | FREE

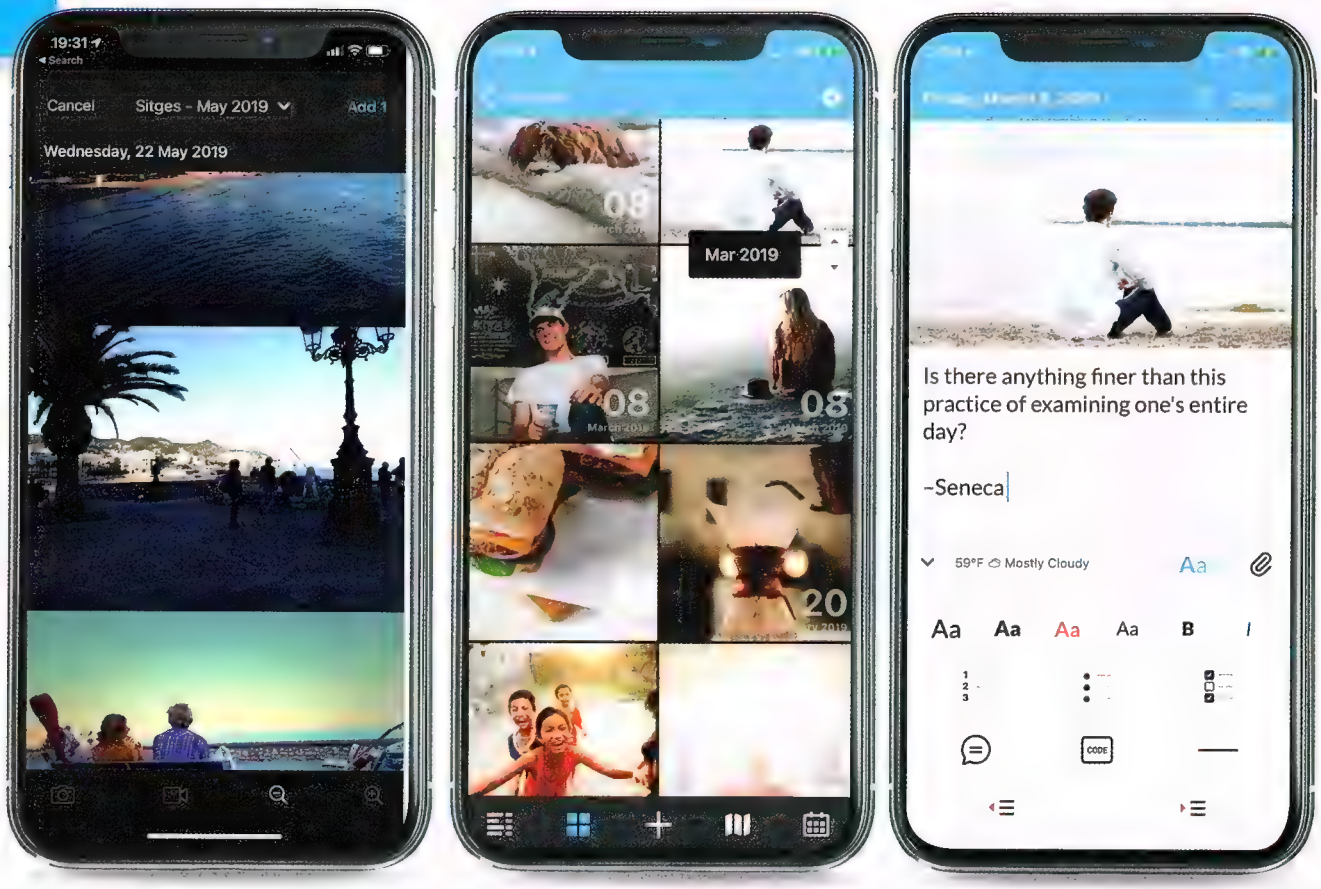
Want to start your own book club? This app is a great way to do it. Use it to keep track of meeting dates (whether in person or on a video call), what you're supposed to be reading, what your list for the future is, and what you've read in the past. It has a useful 'poll' function built in, so the whole group can vote on what to tackle next time, from anywhere.


FOLK HORROR
Explore the eerie power and sinister possibilities of nature and country life.
Perfect First Listens
Outlander
Normal People
Subtle Art of Not Gi...
Top New Releases

Audiobooks.com

NEEDS iOS 10 or later | US$14.95 a month

Like the idea of audiobooks but aren't keen on Audible? This is a great alternative, with over 200,000 books, including 8,000 free titles. It also has 1.2 million podcasts. Like Audible, you pay per month, and you get a credit for a free book each month. The app will make smart recommendations based on what you've enjoyed previously, too.



iOS
needs iOS 13.1 or later | Free | dayoneapp.com

Day One Journal

Record your daily thoughts.

In the year since we reviewed journalling app Day One Journal, it's acquired several new features that may persuade you to give it a try – or to upgrade to premium if you're still using the basic version.

Top of the list of new features in version 5 is a Today view that redesigns the Activity Feed. It pulls together location, calendar, events, photos taken, entries for the day and those for On this Day, giving you a quick overview of any day. To access it, you simply tap a date, either in the calendar or timeline, or tap Today in the side menu.

Version 5 also gets a new media picker that allows you to zoom in on photos and videos, toggle between your photo library and the camera, and organises photos by location and time of day.

There's also a redesigned PDF exporter. And you can now give a location any name you like and the location will be renamed throughout the app, including in previous journal entries. And the iPad version gets new keyboard shortcuts – particularly useful if you tend to use your iPad with an external keyboard.

Since we last reviewed it, in updates to version 4, Day One Journal has also gained a templates gallery and daily prompts to help you get started writing. In fact, a number of new features have been added regularly throughout the last year. But limitations on video import remain; 1080p or lower resolution and less than three minutes.

Day One Journal now provides daily prompts to help you get started with the day's entries.

Solid additions

Day One Journal is fun to use, but we wish the new zoom tool in the media picker was more fluid rather than stepping between three size options. And performance felt a little sluggish on our iPhone XR running iOS 14. We like the way it plays nicely with other apps and services, though, such as the ability to share entries using Share Sheets or import files from the Files app as attachments.

These are solid additions to what was already a good journalling tool. However, it's unlikely that anyone who hasn't already been tempted to pay for the premium version ($55.99) will change their mind or that those who haven't given Day One a go will do so on the basis of this version.

KENNY HEMPHILL

A solid yet uninspiring update for existing users, but it's unlikely to attract many new ones.

★★★☆☆

ANDROID/IOS

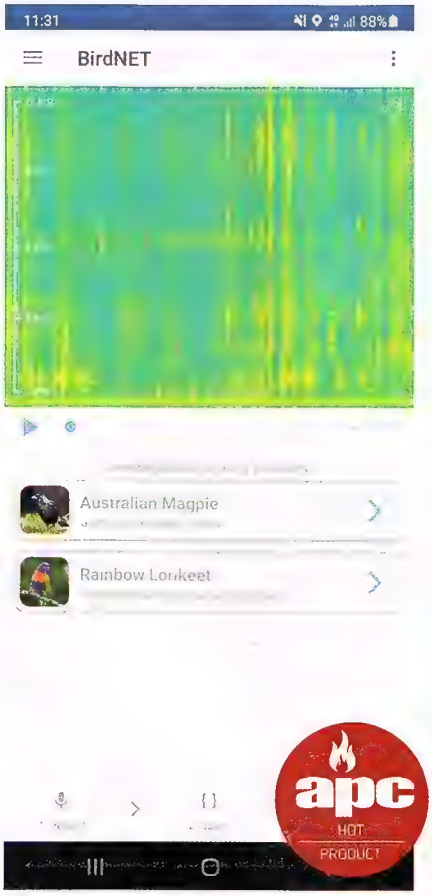
Readly

You may already be using it.

Free / $9.99 per month

I might be taking a leap here, dear reader, but something tells me you don't mind the odd magazine in your life. If my massive assumption is correct, then maybe you should look into this app called Readly. Readly is a magazine and newspaper subscription service app that compiles over 5,000 publications into the one app. They happen to include this one, by the way, but there's a tonne of others. *The Guardian*, *Time*, *Women's Weekly*, *K-Zone*, *Australian Muscle Car*, etc. Just a huge variety of magazines all readable within the app. They present as they would appear in print, which looks cool but can be difficult to read. Thankfully there's a reader button to make that easier - but it's not as pretty, so it's good Readly offers both options. You can even just choose articles from all the publications and have them curated to your interests. The first month has a free trial, then after that it's a $10 per month sub, which feels like a pretty good deal for the mountain of content.

★★★★☆



Android/iOS

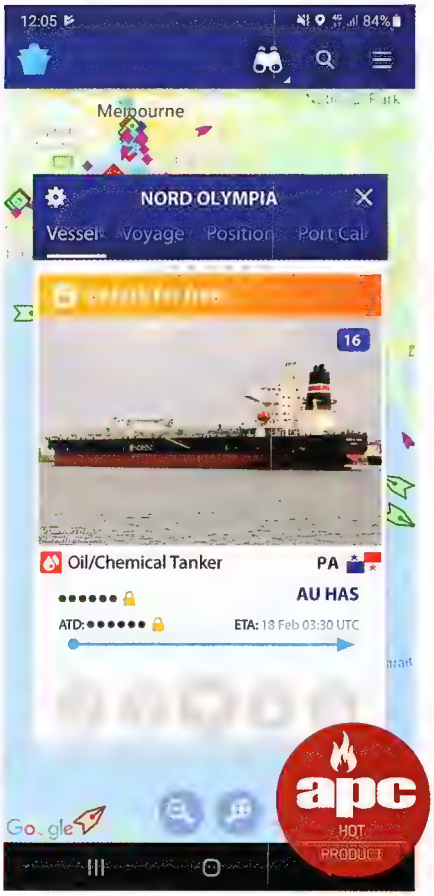
BirdNET: Bird sound identification

Bird ID.

Free

Birds are cool. Or they are really annoying. Either way, it's generally good to know which birds you are enjoying or being annoyed by. BirdNET: Bird sound identification is a cute app that listens to birds, and then tells you what they are. BirdNet does this by isolating a portion of the recording and analysing it. So far, it's correctly recognised every bird I've tried. It gets a bit cooler though. BirdNet will log the birds you've heard, so you get your own fun game of bird watch (listen?) bingo. It also shows you a list of birds that might be in your area for the time of year, so you know what to expect. It's free and developed by a team of biologists and engineers who seem to just really love birds and helping you find out what they are. It's one of those labour of love style apps that works because it's made by passionate intelligent people.

★★★★★



Android/iOS

MarineTraffic - Ship Tracking

Fleets.

Free / $7.99 / other subs

I need to fist say that I don't really know anything about modern maritime... well anything really, but this app seems to and that's really cool. MarineTraffic - Ship Tracking lets you see ship activity all over the world mapped out in somewhat real time. It will tell you where that vessel is from, where it's going, and what the last time it checked in is. Then you can select ships to find out more information about them and even see photos. It feels kinda like looking at ship trading cards and is just a fascinating thing to do. If you have an account you can create your own fleets and follow them! Move over fantasy football, I'm only into fleets now. There is some info hidden behind a $15.99 per year paywall, but you get a few free unlocks to try out first. This adds a lot of cool features like augmented reality and weather forecasts, but might only be interesting for enthusiasts. Either way, it's very cool to check out and just see what's around.

HOPE CORRIGAN

★★★★★

acer
acer
acer
SWIFT

BLUE BLOOD:

The best of Intel's 2021 Evo laptops

The next evolution of Intel's Project Athena laptops are here and Joel Burgess has put them through their paces to sort the pedigree Ultrabooks from the runts of the litter.

Intel's Project Athena was announced back in 2019, as a program to encourage laptop vendors using 10th Gen Intel chips to optimise their devices along a few key lines that the company believed would be most critical to today's consumers. After a year of extensive uptake across thin-and-light laptops, Intel says it's learnt a lot from the program already and has expressed these findings in the next generation of Athena: Intel Evo.

What is Evo?

To make the cut, an Intel Evo Laptop needs to offer stable performance throughout its battery life, wake from sleep in less than a second, maintain over nine hours battery life on real-world use benchmarks, and offer four hours of battery life from a 30 minute fast-charge.

The main other standout features you'll see on all Evo laptops is Wi-Fi 6 compatibility and Thunderbolt 4 interface connections. While the new Wi-Fi spec could reasonably be expected on all new laptops, ensuring a consistent Thunderbolt spec is actually a great way to make the shared USB/Thunderbolt ports a little more predictable for everyday consumers. With multiple generations of both technologies competing through the same USB Type-C connection, knowing exactly what port is installed has become increasingly complicated on today's laptops.

Intel 11th Gen

In addition to the tweaks you'll see through the Evo certification process there's also the obvious underlying requirement of running one of Intel's 11th generation Ultrabook processors. The new chips offer 10-14 percent better general computing performance in multithreaded CPU tasks according to our internal testing, and up to 20 percent improvements on work applications according to Intel.

What is even more significant, however, is the generational graphical improvement. Intel is claiming its new Iris Xe integrated graphics processor is twice as fast as Intel's Iris Plus or UHD Graphics on 10th generation chips. The improvement was a little bigger at 2.23 times the performance on 3D Mark Time Spy averages across the two cohorts, according to our testing – a difference big enough to put light gaming on the agenda.

With playable 30fps+ framerates on titles like *The Division 2*, *Total War Saga: Troy*, *Metro: Exodus*, *F1 2020*, and *Sid Meier's Civilization VI* when using 1080p resolution and Low graphics quality – it's fair to say that Evo laptops are the first generation to bring proper entry-level gaming to the Ultrabook.

Taken together this is a considerable generational update that gives consumers a number of reasons to upgrade their Ultrabook. It also shows off Intel's potential for continued dominance in the increasingly competitive Windows 10 Ultrabook market.

While it's great to see Intel pushing the consumer agenda forward, with so many stipulations on what laptop vendors can do, we wonder – will it be possible for laptops to differentiate themselves from other Evo laptops on the market?

Read on to see what separates the truly great Ultrabooks of 2021 from the rest of the pack.

$2,399 | acer.com.au

Acer Swift 5

Is Acer's speedy Ultrabook the best in the business this year?

With an RRP of $2,399 the Swift 5 from Acer is the equal best value device here alongside the MSI Prestige 14 Evo, but we've seen it on Acer's online store for $2,047. If you can get it at this price then the Swift 5 offers unbeatable value, but even at it's RRP this is a solid offering. Not only is this device one of the thinnest of the roundup at 1.5cm thick, it was also the lightest (per square inch), weighing in at just over a kilogram. While it does feel a little less premium, using lightweight metals on the keyboard surround and top shell, Acer has actually done a great job maintaining continuity through to the plastic undercarriage, which means it doesn't detract at all from the overall experience.

The keyboard has a slightly smaller footprint than some here and the keys aren't overly deep. They don't offer that much tactile resistance and will be a little loud for some, but they're comfortable to type on for long periods of time. The trackpad is also soft and responsive enough to not be an issue, and there's more connectivity options here for those keen to have HDMI and USB Type-A connectivity.

SPECS
Acer Swift 5, Intel Core i7-1165G7, 16GB, Intel Iris Xe Graphics, 1TB PCIe SSD, Intel Wifi 6 AX201, 14-inch, IPS touchscreen, 1920x1080, Gloss, 54Wh, 318.9x206.98 x14.95, 1.5cm, 1.02kg.

The Swift 5 even performed consistently above average in our tests and, similar to others here, netted playable frame rate averages around 35fps for *The Division 2* and *Metro: Exodus*.

Battery life was decent, lasting eight hours and 54 minutes in 1080p movie playback and while the 14-inch IPS touchscreen wasn't standout, it had nice enough colour reproduction and functionality to be appropriate as a premium display.

A great value ultra-portable laptop that performs as well as any other 2021 Evo we've seen.

★★★★★

$2,599 | xpg.com

Adata XPG Xenia Xe

Should Intel be leaving the laptop making to the lifestyle brands?

With the ongoing advance of AMD into the laptop processor space and the loss of Apple processor manufacturing contracts, we're not overly surprised that Intel is keen to start building more of its own devices. The XPG Xenia Xe is the second 15-inch NUC to come from Intel, but considering the processor manufacturer isn't on top of its game in other areas, is it stretched too thin to make a successful laptop?

The XPG Xenia Xe is a 15.6-inch Full HD professional ultrabook that has a simple, squarish silver shape and an inoffensive overall layout. The keyboard's keys are a little smaller than they needed to be, with a large chassis area around them, but they offer enough resistance and travel to be fine for typing.

If you're keen on battery life, bigger screens and the fastest storage around then the XPG Xenia Xe should be up the top of your shortlist for sure. Managing around 13 hours in 1080p movie playback, it's one of the longer lasting professional ultrabooks we've tested, and it's also one of the first 15-inch Full HD screens we've seen in 2021. Both the i5 and i7 models also get a generous 1TB allocation of PCIe Gen 4 SSD storage that'll read and write between 4,000 and 5,000MB/s, which is a considerable jump over the last generation of storage performance.

SPECS
Adata XPG Xenia Xe,i7-1165G7, 16GB, Intel Iris Xe Graphics 1TB XPG Gammix S50, Intel Wifi 6 AX201, 15.6-inch, 400nit, 1920x1080, Gloss, 72.6Wh, 335x230x14.9 1.5cm, 1.65kg.

The 11th generation Intel processors give the XPG Xenia Xe a solid base of general processing power, but the new integrated Iris Xe GPU is still the star attraction, delivering playable frame rates on most modern games at 1080p resolution and dialled-down graphics settings.

An excellent laptop if battery, screen size and speedy storage are the most critical elements for you.

★★★★½

$2,299 | asus.com

Asus ZenBook Flip 13

Asus is showing its mastery of laptop design in another flexible convertible with premium perks.

The Asus ZenBook Flip 13's 1080p screen is a 13.3-inch OLED panel with Full DCI-P3 colour compatibility, which is a pretty standout bonus in an otherwise tight race... especially when it'll cost you nothing extra.

The standard online price for the ZenBook Flip 13 with a Core i7, 16GB of RAM and 512GB PCIe SSD is $2,299, but we've seen it on sale for as little as $2,077 – which is on par with the best price for an i7 Evo we've seen. It also comes in an i5, 8GB, 512GB variation (still with the OLED panel) for $1,699 full-price or $1,598 on sale.

The keyboard is a little elongated, but this doesn't seem to affect the overall typing experience too much. The backlit trackpad, which is now super easy to turn on and off, means the responsive trackpad doubles as an awesomely convenient number pad.

We're guessing Asus did some component binning, as this more affordable laptop takes a little bit of a hit in general performance benchmarks, but it's less than 10 percent generally. The gaming performance was a little more disappointing, with unplayable average frame rates in both *The Division 2* and *Metro: Exodus*. The ZenBook Flip 13 did achieve parity in synthetic GPU testing however, so we suspect these GPU performance issues can be solved by tweaking some power settings and updates to software.

Storage was also the slowest of the pack, but it's still a 2,000MB/s PCIe storage device, so it won't feel sluggish by any means. Battery life was also solid, getting more than 10 hours in both PCMark 10 and 1080p movie playback benchmarks.

SPECS
Asus ZenBook Flip 13, Intel Core i7-1165G7, 16GB, Intel Iris Xe Graphics, 512GB PCIe SSD, Intel Wifi 6 AX201, 13.3-inch, OLED, 1920x1080, Gloss, 69Wh, 305x196x16.9, 1.7cm, 1.3kg.

Our overall pick for this years best value Evo Ultrabook with a standout OLED screen.

★★★★★

$3,699 | dell.com

Dell XPS 13 2-in-1

The gold standard of convertible Ultrabooks will be tough to beat this year.

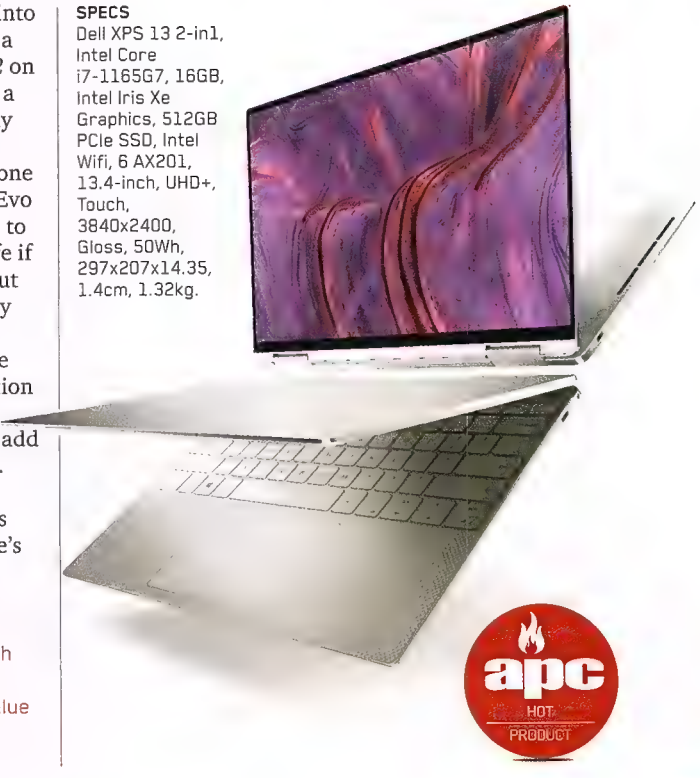
While some of the XPS 13 2-in-1s offered by Dell are overpriced, there seems to be a rolling deal on the most popular i7, 16GB, 512GB SSD, FullHD+ model, which lands at a more competitive $2,399.

At this price, this 13.4-inch FullHD+ convertible laptop offers a solid pedigree that's expressed in sophisticated materials like an insulating carbon fibre keyboard surround, minimal exposed air vents and delicately weighted, fully-rotatable hinges. The keyboard isn't particularly deep, but it has a signature clicky feel and sound that is appreciated by many and makes for a nice overall typing experience.

While some performance benchmarks pegged this unit around the middle of the pack, others suggest that the XPS 13 2-in-1 was tuned to go as fast as it could, showing up to 30 percent improvements over Evo averages on media encoding and CPU rendering tasks. Some of these performance gains continued into graphical capabilities, scoring a 41fps average in *The Division 2* on 1080p low, but it does come at a cost of battery life. Lasting only five hours and 48 minutes in 1080p movie playback, it was one of the most fleeting here. The Evo spec means you should be able to get a full work day's battery life if you dial down performance, but we suspect this will temper any performance benefits.

The screen is vibrant and the slightly taller 16 by 10 proportion is a nice touch. If you do want 4K+ resolution then expect to add $1,300 to the overall price tag. FullHD+ was enough to comfortably work on and looks good during playback, so there's no real need for the upgrade.

SPECS
Dell XPS 13 2-in1, Intel Core i7-1165G7, 16GB, Intel Iris Xe Graphics, 512GB PCIe SSD, Intel Wifi, 6 AX201, 13.4-inch, UHD+, Touch, 3840x2400, Gloss, 50Wh, 297x207x14.35, 1.4cm, 1.32kg.



Still one of the best-built 13-inch convertibles you can buy, with some models offering better value than others.

★★★★½

$2,110 | anz.dynabook.com

Dynabook Portégé X30W-J

Is Sharp's inherited professional laptop range capable of reaching its potential?

It's easy to see Toshiba's legacy in everything from the lightweight metal chassis design to the thin bezel implementation on the Dynabook Portégé X30W-J, but some elements – such as the trackpad – look and feel a little dated in a lineup of 2021 Evo laptops. Sharp still has some honing to do on its adopted Protégé.

Dynabook is claiming its Portégé X30W-J is the lightest 13.3-inch Evo device around, and so far we haven't seen anything to contradict that; however the slightly larger 14-inch Acer Swift 5 has a better kg-per-inch weight to screen-size ratio. Unfortunately, the Portégé X30W-J's lightweight materials combined with the mushier than usual keyboard make this device feel a little less premium than its competitors here, but it's not bad enough to be a deal breaker.

The Portégé X30W-J is one of the few units in this round up to feature Windows 10 Pro, and the model we tested came with an Intel Core i5-1135G7 CPU. With a starting price of around $2,148 when paired with 8GB RAM and 256GB of storage, we'd opt to double the memory and storage offerings for $150 extra or go for the i7, 16GB, 512GB variation for $2,419.

SPECS
Dynabook Portege, X30W-J, Intel Core, i5-1135G7, 16GB, Intel Iris Xe Graphics, 256GB Samsung PCIe, SSD, Intel Wifi 6, AX201, 13.3-inch, 10 point touchscreen, 1920x1080, Matte, 53Wh, 303.9x197.4x17.9, 1.8cm, 989g.

In most tests the i5 Dynabook Portégé X30W-J performed around 10 percent behind the i7 Evo average, but this should still be more than enough for most workflows at roughly the same performance of a 10th Gen i7. With similar relative GPU performance you can still expect to play most games on low 1080p graphical settings and you'll get eight hours and 26 minutes out of the battery in 1080p movie playback.

A good Evo workhorse for those that care more about convenience than appearances.

★★★★☆

$2,999 | harveynorman.com.au

HP Spectre x360 13t-aw200

Is HP's sleek convertible good enough to convert anyone in 2021?

While there will be a couple of different variations on the Spectre X360 this year, the model we're testing is only available at Harvey Norman for an RRP of $2,999. This might seem steep for a 13.3 inch laptop with just a 60Hz Full HD panel, but this screen is actually an OLED display, which makes it stand out in media playback and general colour reproduction in side-by-side comparisons. The Spectre x360 13t-aw2007tu also features an Intel Core i7-1165G7 CPU, 16GB of RAM and an integrated Intel Iris Xe GPU, which rounds out a nicely balanced spec sheet for a premium work productivity laptop.

The 11th Gen processors offer predictable ten-percent-ish improvements over last year's laptops, but the Spectre x360 13t-aw2007tu we tested generally netted below average performance results against this year's cohort.

SPECS
HP Spectre X360, 13t-aw2007TU, Intel Core i7-1165G7, 16GB, Intel Iris Xe Graphics, 512GB Intel Optane PCIe, SSD, Intel Wifi 6 AX201, 13.3-inch, 10 point touch, IPS, 1920x1080, Gloss, 62Wh, 306.7x194x16.9, 1.7cm, 1.32kg.

Generally the x360 was behind by less than 15-percent, but that margin did dip to over 20 percent in some CPU tests, like 4K media encoding. Graphically it was even worse, with benchmark tests being between 10 and 55-percent behind the pack averages, making many of them unplayable. We're hoping that this model is abnormal in its performance, but since there's nothing obviously wrong with it we have to assume that it's as intended.

Keyboard and trackpad are nice enough to avoid being called out and the B&O speakers, fingerprint reader, relatively broad interface options and unique design give it all the trimmings of a good professional laptop. Unfortunately price and performance just aren't overly competitive this year.

A longstanding Ultrabook competitor that has taken a misstep on price and performance on this particular model.

★★★☆☆

$2,398 | au.msi.com

MSI Prestige 14 EVO A11M

Has MSI mastered the art of business laptops?

MSI has been making some good laptops of late, and the Prestige 14 Evo isn't about to break that streak. Coming in at just 1.29kg the Prestige 14 EVO is on the lighter side of 13-inch laptops available in 2021. At first glance it might feel like it's made out of cheaper materials but the sandblasted aluminium provides a sturdy shell that prevents any flex and helps keep it under 1.6cm thick. It looks like there's really only one configuration available locally, featuring an i7-1165G7 with Iris Xe GPU, 16GB of RAM and a 512GB PCIe SSD. This unit is one of the few to feature a 4th generation PCIe SSD, which means you can expect ridiculously fast read speeds of 4,910MB/s... even if we could only get this one to 2,508MB/s when writing.

Performance is on par with what you'll see from the rest of the units here. This means it's powerful enough to accommodate the workflows of most business users, with only designers and other creative pro's needing a little more under the hood. As with everything here you also get the Iris Xe GPU gaming capabilities which means you'll get playable frame rates for low 1080p settings on many modern games.

Apart from the 4th-gen PCIe SSD, the main drawcard of the MSI prestige is the price, which is on the more affordable end without sacrificing on components. If you need a high-res screen you'll have to look elsewhere, but everything else on this unit is top notch.

SPECS
MSI Prestige 14 Evo A11M, Intel Corei7-1165G7, 16GB, Intel Iris Xe Graphics, 512GB, PCIe SSD Gen 4, Intel Wifi 6 AX201, 14.0-inch, Low power IPS, 1920x1080, Matte, 51Wh, 319 x 219 x 15.9, 1.6cm, 1.29kg.

Great all-round professional device at a reasonable price.

★★★★★

$3,799 | razer.com/au-en

Razer Book 13

Is Razer's first proper pro laptop a performer?

Razer is finally branching out into the 'strictly business' space with the new Book 13 line by ditching the discrete GPU and slashing the price. It's a solid move, but with Apple and Dell both offering price cuts on its 2021 devices, the Book 13's starting price of $2,199 isn't as competitive as we'd hoped.

For that starting price you'll get a non-touch 13.4-inch 16-by-10 display at FullHD+ 60Hz, an Intel Core i5-1135G7 CPU, 16GB of RAM and a 256GB SSD, which is a couple of hundred dollars less than Dell's XPS 13, but a few hundred more than a similarly specced MacBook Air. If you want the more powerful Intel Core i7-1165G7 under the hood and touchscreen capabilities you're looking at $2,999, while the top of the line UHD+ display will cost you $3,799.

The Razer Book 13 offered above average performance on just about every parameter, so it's clear Razer will go above and beyond when tweaking its systems, but the difference was small, generally under 10 percent so it won't make a huge difference. The Iris Xe GPU will boost productivity for anyone occasionally doing graphically intensive work and it's enough for those who want to occasionally play less demanding games.

SPECS
Razer Book 13, Intel Core i7-1165G7, 16GB, Intel Iris, Xe Graphics, 512GB PCIe, Intel Wireless-AX 201, 13.4-inch , 60Hz Corning, Gorilla Glass, 3840x2400, Gloss, 55Wh, 295.6x198.5x 15.15, 1.5cm, 1.4kg.

The keyboard is a little more compact than we'd like and while the keys had a good level of resistance, they are slightly too small and skew to the right.

Seven hours and 40 minutes in PCMark 10's Work battery benchmark is one of the shortest lifespans here, but battery life is still pretty good if you compare it to devices from last year.

A great first laptop from Razer that will need more competitive pricing to get an edge.

★★★½☆

Indicates best result

	PCMARK 10		BATTERY (MOVIE PLAYBACK)	CRYSTAL DISMARK 5/6	
	OVERALL SCORE	BATTERY WORK (H:MIN)	1080P TOTAL PLAYBACK TIME (H:MIN)	SEQUENTIAL READ (QT32T1)	SEQUENTIAL WRITE (Q32T1)
Adata XPG Xenia Xe (Intel NUC M15)	4,750	9:13	12:50	4,979	4,245
Acer Swift 5	5,051	9:57	8:54	2,208	1,979
Asus ZenBook Flip 13	4,448	10:00	10:51	1,981	981
Dell XPS 13 2-in-1	4,557	8:51	5:48	2,314	1495
Dynabook Protege X30W-J	4,345	12:15	8:26	3,457	2,352
HP Spectre X360 13t-aw2007TU	4,420	9:18	7:55	2,479	1,276
MSI Prestige 14 Evo A11m	4,528	7:38	6:57	4,910	2,508
Razer Book 13	4,886	7:40	9:41	3,536	2,989
Evo Average	4,620.62	9:21	8:56	3,233	2,228.12

Is Evo a winner?

Intel has once again done what it does so well – establish excellent baseline specs for its partners.

Intel has done a lot of work to ensure laptop vendors are delivering outcomes that consumers actually want in 2021, which means you could pretty much pick any Evo laptop at random and you're going to end up with a decent professional Ultrabook. While great for consumers, it makes it difficult for vendors to differentiate their products from the crowd and so price was a critical factor this year. Devices with long pedigrees continued to charge premiums, but with Intel performing quality control checks, it really opened the door for up-and-comers to undercut the more established competition.

The Most Evo-lved

The three winners in this roundup were all the most competitive on price but also managed to squeeze some value-add components into their setups without jettisoning anything critical. Asus's ZenBook Flip 13 was our top pick overall, primarily because it was able to drop an OLED screen onto the unit without adding to the cost. In addition to this the device offers a trackpad that doubles as a number pad, a 4,096 pressure point stylus, 10-point touchscreen with convertible hinge and broad interface compatibility for the lowest overall price. A pretty amazing achievement if you ask us.

The two runners up were the Swift 5 from Acer and MSI's Prestige 14 Evo, which were both great value, but also included storage bonuses. Acer's was simpler in that it was just bigger, but MSI actually installed a 4th generation PCIe SSD, which can read and write more than twice as fast as what's in the ZenBook Flip 13.

Dell has a loyal following that will forgo bells and whistles just to not have to live without that keyboard, and for the models it discounts this isn't unreasonable. Intel also gave it an admirable crack themselves in the NUC M15, which Adata was able to add value to by installing the fastest SSD too.

Everyone's a winner

What was perhaps most impressive is that all these devices now offer reasonable entry level gaming capabilities, and there's no longer laptops that'll only last half a day. When taken together this is a pretty awesome step in the right direction that makes 2021 Evo devices compelling for anyone considering an upgrade.

"This is a pretty awesome step in the right direction that makes 2021 Evo devices compelling for anyone considering an upgrade."

CINEBENCH R5	GEEKBENCH 5		HWBOT X264	TEMPERATURE	3D MARK (2013)	THE DIVISION 2
CPU	SINGLE-CORE	MULTI-CORE	1080FPS	PEAK CPU TEMPERATURE (C°)	TIME SPY	1080, LOW (AVG FPS)
1,174	1,527	4,156	25.84	98	1,796	31
2,052	1,522	5,833	24.29	100	1,621	35
1,737	1,566	5,207	18.80	95	1,490	23
2,060	1,296	5,611	27.83	100	1,723	41
1,930	1,386	5,158	21.36	88	1,496	31
1,499	1,567	4,984	17.65	99	1,248	20
1,281	1,500	4,617	1.705	99	1,535	28
1,860	1,563	5,427	23.03	100	1,698	33
1,699.12	1,490.87	5,124.12	21.57	98	1,572.75	31.5

FEATURE

THE GRAPHICAL UNION ADDRESS: NOW WITH MORE RAY TRACING

The ray-tracing party is kicking into full swing, with AMD arriving fashionably late. Jarred Walton takes us on the tour.

Over two years ago, Nvidia surprised nearly everyone by announcing that its next-gen Turing architecture would feature the holy grail of computer graphics: Ray tracing (RT). It's a technique that's been around for decades, and the movie industry makes extensive use of it these days – or at least it did, back when movies were still being made, and we could go out to watch them. The thought of getting hyper-realistic visuals in games that could rival the latest blockbusters sounded too good to be true, and it was. Today, we have Nvidia's second generation of RT hardware in the Ampere architecture, and AMD has joined the fray with its RDNA2 GPUs. It's time for a State of the Union address on the subject of ray tracing in games...

A brief overview of RT Effects

We're not going to dig deep into the details of how RT works – that's familiar territory by now. The short summary is that it involves calculating the projection of lines (rays) into the geometry of a scene to figure out what polygon the ray intersects, and then depending on the material properties of that polygon, additional rays can be cast. Ultimately, the results of all those individual rays are then combined to determine the final colour value for a pixel.

While it might seem like a single ray per pixel would suffice, it doesn't really get the job done. Each bounce counts as a new ray, and there are different types of material and ray calculations that need to be done. The main takeaway is that fully ray-traced scenes in movies can use hundreds or even thousands of rays per pixel, and take hours of rendering time per frame. That's many orders of magnitude slower than what we want from PC games. Even a relatively "fast" rendering time of 10 minutes per frame in a movie is still about two million times slower than a PC game running at 60 frames per second.

The trick for real-time ray tracing is to find a compromise between quality and performance. GPUs containing RT hardware aren't going to give us a million-fold speed-up, but by combining the results of rasterisation where it looks good enough with RT, it's possible to get hybrid rendering up to real-time levels of performance. That's the idea, at least.

In general, rasterisation is really good at handling textures and geometry, and shader calculations and post processing effects can further improve the resulting output. Ray tracing doesn't need to reinvent the wheel, then, but instead just focus on improving the areas where rasterisation comes up short. Here's a quick overview of the major RT effects being pursued right now in games.

The use of RT for global illumination, shadows, and reflections enhances the road rage of the Night City denizens when someone parks their car in the middle of the road.

Bright Memory Infinite does multi-bounce reflections. With a single bounce, the reflected car window would be blank rather than showing the woman's face.

Ray-traced effects

•**REFLECTIONS:** This is a great example of where RT has real advantages over traditional rendering modes, as the rays can bounce into areas of the scene that aren't directly visible. It's easy to set up an environment where the presence or lack of proper reflections makes a huge difference in how things look – 2019's *Control* being a great example with its mirrored office environments. You can even take things a step further with multiple bounce reflections, where a ray that hits a reflective surface and bounces into another reflective surface keeps propagating, which is required to render a hall of mirrors effect. Of course, more reflections and more rays mean slower performance, but the *Bright Memory Infinite* demo has some great examples of how more complex RT modes can improve the overall visual fidelity.

Right now, the list of games using ray tracing for reflections continues to grow, with at least 10 games released and more on the way. *Control*, *Cyberpunk 2077*, and *Watch Dogs Legion* are some of the best examples. The problem is that even though reflections can make a big visual difference, there are still scenes where they hardly matter, yet the performance hit remains. Plus, even though screen space reflections miss some things (stuff that's not currently visible on the screen can't be reflected), SSR often does a reasonable job at faking it.

Limited RT reflections can also break the illusion the game is trying to create. Case in point: *Cyberpunk 2077* apparently doesn't have a model for the player character V present in the game world. That or V is for "vampire" and so V doesn't cast a reflection. Either way, it feels very weird to walk up to a car window and not see your player. Oddly, you can "turn on" mirrors in bathrooms to

PICS: CD PROJEKT, FYQD STUDIO, PLAYISM, ACTIVE GAMING MEDIA

see your reflection, and V is present in the game's photo mode, but after playing *Control* and *Watch Dogs Legion*, *Cyberpunk 2077*'s missing reflections just feel wrong – and may end up getting patched by the time you read this.

•**SHADOWS:** Proper shadows require looking at how much light reaches each surface, which can be incredibly computationally expensive if there are lots of lights in a scene – not to mention surfaces that can reflect lights. Most games tend to implement RT shadows for only a few light sources, focusing on those that are within a certain distance from the objects, plus a single global light source.

Our impression is that RT shadows are at the other end of the spectrum from reflections, in that they've been decidedly disappointing so far. It's not that RT shadows don't make a difference in visuals, but do they make a big enough difference? That's the rub. In practice, shadow-mapping techniques tend to look good, and more advanced solutions can mimic soft shadows while still performing better than RT shadows. *Shadow of the Tomb Raider* and the two latest *Call of Duty* games are good examples of how little RT shadows often matter, and they still generally omit proper shadows for things like procedurally generated foliage.

•**GLOBAL ILLUMINATION / LIGHTING:** This one gets a bit nebulous – isn't lighting sort of the same as shadows? But here the focus is on figuring out how much indirect lighting reaches a surface, as well as the colour of the lighting. For a pure RT implementation, it's possible to basically lump a lot of these effects together in a single unified engine, but then we're back to millions of times more complexity than is perhaps necessary for a game.

Metro Exodus only used RT for GI, and it could certainly make a difference inside some buildings. One example that was shown when the game launched was how proper GI leads to darker shadows in some areas of a room, but lighter areas in others. A building with a single window to the outside, for instance, doesn't just have a bright rectangle where light enters the room. Instead, you get a lit-up area

Pure ray-tracing performance?

How far are we away from doing pure ray tracing in a game? Theoretically, it could be done right now, but how would it perform? The best estimate we have of how a pure RT rendering solution would perform comes from 3DMark, with its DirectX Ray Tracing Feature Test. We ran the test on the latest AMD and Nvidia RT-capable GPUs, and it uses a relatively ambitious 2560x1440 resolution. Full ray tracing at 1440p? We could be in for a bumpy ride!

3DMark DXR Feature Test (avg. FPS)

RTX 3090	RTX 3080	RTX 3070	RTX 3060 Ti	RX 6900 XT	RX 6800 XT	RX 6800

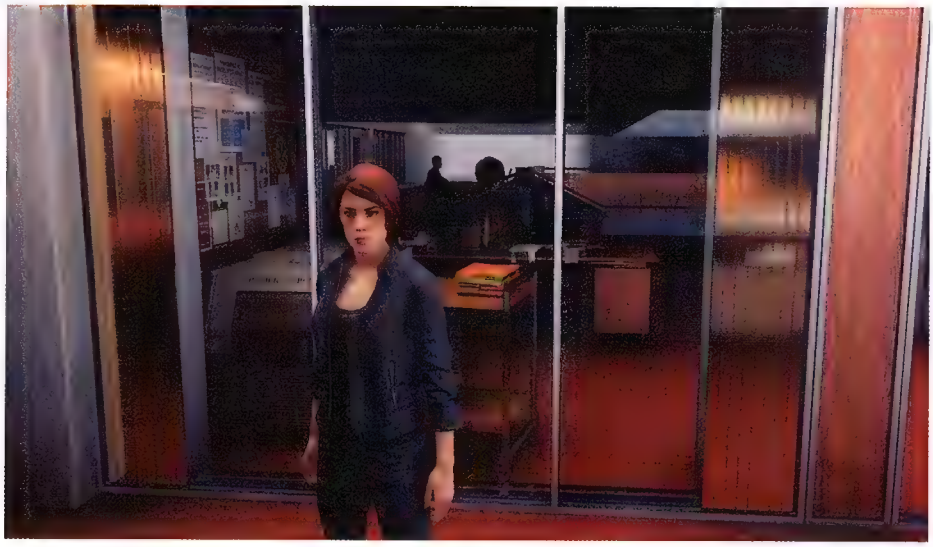
OK, honestly that doesn't even look that bad. The 3090 is already hitting nearly 60fps! Except, you have to see the test in action to understand what's happening, and how it differs from a real game.

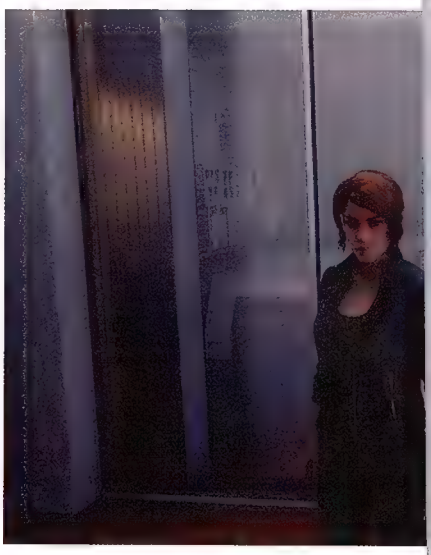
The whole test uses a static scene, and the camera moves around, adjusting focal length at times. Once the camera stops moving, the randomised rays being cast converge on an ideal ray-traced rendering of the scene, and things look pretty good. But when the camera's moving, each pixel only gets 12 rays cast per frame, which results in pixel noise – especially apparent on the slower GPUs.

So, maybe this isn't a true representation of a fully RT game engine. However, it does give us an interesting comparison of the latest GPUs, and the picture it paints doesn't look too good for AMD. AMD's fastest GPU, the 6900 XT, barely beats Nvidia's 3060 Ti. AMD also falls behind Nvidia's previous-generation RTX 2080 Ti. What's particularly concerning is that even the RX 6800 is faster than the new consoles, which means the best the consoles can hope for is about one-third of the pure RT potential of the RTX 3090.

Call of Duty focuses its use of RT on shadows and ambient occlusion. These improve the overall feel, but rasterisation looks good anyway.

PICS: ACTIVISION BLIZZARD





Control is filled with reflective surfaces, including puddles, mirrors, and glass, combined with RT shadows and diffuse lighting.

that in turn makes the rest of the room at least partially visible. Without RT, most games define a general minimum lighting level so that non-lit areas aren't just black, but it's not realistic.

The problem is that sometimes realism isn't as fun. There's a scene in a helicopter in *Cyberpunk 2077*, for example, that takes place at night. With RT enabled, all you can really make out is the dark silhouette of a person aiming a mounted minigun. Turn off RT and suddenly there are multiple people and lots of equipment inside the helicopter. It's not necessarily that the RT implementation is wrong, but in the real world there would likely be other light sources that simply aren't included in the game.

•AMBIENT OCCLUSION, REFRACTIONS, AND CAUSTICS (OH MY!): These last three effects aren't quite as eye-catching as the above, so we're putting them all into one pot. Refractions have to do with the way light bends as it passes through a transparent object, such as glass or water. Frankly, a rough approximation of the distortion done via shaders is probably good enough for most games. Caustics is related to refractions, and has to do with the bright focus areas of light that you can get, such as with a magnifying glass or even a glass of wine. Cool? Perhaps, but also not critical for most games. Then finally there's AO, which focuses on the way shadows tend to be darker in corners where polygons intersect.

The story is pretty much the same for these as for the earlier RT effects: Some things clearly look better, while other aspects hardly seem to change, and the performance hit remains. Can we see the difference between the varying forms of ambient occlusion – SSAO, HBAO+, or RTAO? Yes. Does RTAO look best? Yes. Would we actually notice the change in AO if we weren't specifically looking for it? Perhaps in a more cerebral game, but in a fast-paced shooter, probably not.

Building for the future

What we're getting at is that RT still feels very much in its infancy, as far as games are concerned, and game developers aren't free to focus on the RT implementation as long as a significant percentage of the PC ecosystem still consists of old non-RT GPUs. And it does, if we're going by the Steam Hardware Survey, which shows only 12 percent of all PCs using an Nvidia RTX graphics card (it also shows seven percent of PCs surveyed still using Intel integrated graphics).

This isn't something new or unusual. We've been through this same sort of progression multiple times. There was the shift from 2D to 3D accelerators in the 90s, the "first GPUs" that added hardware transform and lighting support in the late 90s, and multiple generations of hardware-programmable shaders. Each time, it took years before the old hardware was truly abandoned by newer games. The past two years of consumer RT hardware have just been the latest case of hardware preceding the software.

The good news is that things are starting to change. Nvidia is no longer the only ray-tracing solution in town. Now that AMD also has hardware RT support for both PC GPUs and the latest consoles, we could potentially see an acceleration in the use of RT.

When will it become a required feature? Judging by the way things are progressing, we're at least five years away from that happening for the biggest releases, and probably more like 10 years away. Individual games might decide to require RT hardware, but it's going to take a long time before major studios will go all-in on ray tracing.

PICS: 505 Games, Getty Images

With DLSS enabled, and ray tracing disabled, even the 3060 Ti can play *Cyberpunk 2077* at 4K 60 fps, albeit with some loss to fidelity.

RIGHT: Second-gen ray tracing has led to a 70 percent performance increase compared to the 2000 series.

BELOW: AMD's Radeon RX 6000 series is the first AMD GPU to support ray tracing, though it's still early days for performance.

Part of that is simply a matter of economics. Major game launches have already reached the level of Hollywood movies, with costs in the tens of millions of dollars (or more), and that's with relatively tame visuals.

If we want RT games to look anything like RT movies, it will require even more artistic talent to make RT shine. To recover the costs of creating a game, publishers need to be able to sell as many copies as possible, and that sits in direct opposition to the idea of making a game that requires RT hardware support.

In other words, we have the classic chicken and egg scenario. Game developers want more gamers to have RT-capable hardware before they pour resources into creating RT games. Gamers, on the other hand, want to see some real advantages for RT hardware before they're willing to fork over the money for a graphics card upgrade. That brings us to the AMD vs. Nvidia (and maybe Intel) discussion.

Meet the Hardware Contenders

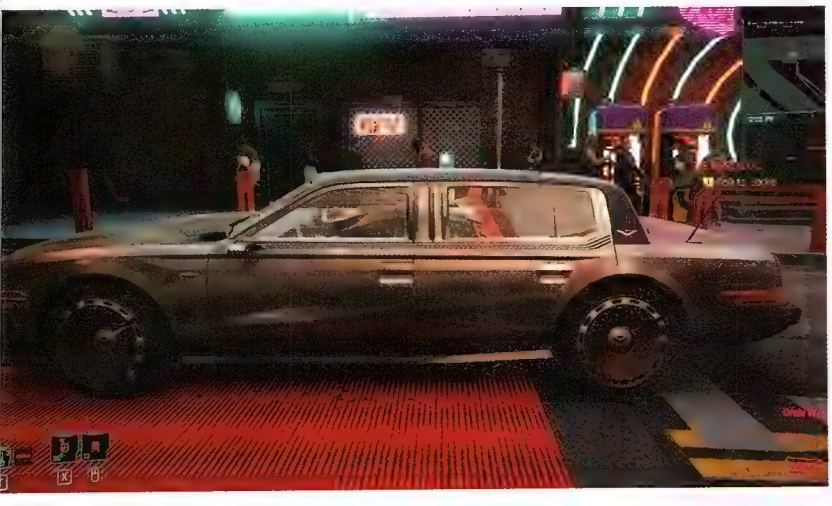
Let's move on from what ray tracing can do for games and look at the hardware implementations. Nvidia has first-gen RTX 20-series GPUs that have defined the baseline for RT performance. The new Ampere architecture ushers in the second round of Nvidia RT hardware, promising up to double the performance for RT calculations. AMD, meanwhile, has just released its first-gen RT hardware, the RX 6000-series RDNA2 GPUs. How do the various GPUs compare in terms of RT capabilities? Well it depends.

Nvidia hasn't disclosed a lot of the low-level details about how Ampere and Turing RT cores differ from each other. We know that Ampere has an additional ray/triangle intersection functional unit, and Ampere's RT cores also have the ability to take a time component (useful for things like RT motion blur). While Ampere is theoretically up to twice as fast as Turing per RT core, in practice Nvidia says that it's about 70 percent faster. Unfortunately, that's only scratching the surface of what the RT cores do and how they work.

For example, we know that Nvidia's RT cores can perform ray/bounding box intersections in addition to ray/triangle intersections. This is all part of the BVH (Bounding Volume Hierarchy) implementation used for RT in both DirectX Raytracing (DXR) and VulkanRT. In short, BVH is a structure that helps accelerate the process of determining which, if any, triangle a ray intersects. Rather than checking the ray against every triangle, it starts with comparing the ray against bounding boxes that get progressively smaller, until the algorithm reaches a point where checking a ray against individual triangles makes sense.

What we don't know exactly is how fast Nvidia's GPUs are at ray/box vs. ray/triangle intersections. There are some situations where Ampere can do twice as many RT calculations per cycle, and others where one of the functional units may go unused. For AMD's part, the RDNA2 GPUs have Ray Accelerators that can do either four ray/box intersection calculations per cycle, or one ray/triangle intersection. It's also unclear if different types of RT calculations – for example, for reflections vs. shadows vs. global illumination – take different amounts of time per ray, or if they simply require more rays in general.

With hardware in hand, however, it's possible to run tests to get a reasonable estimate of the performance – see Pure Ray Tracing Performance on page 51. That's one specific test of RT



PICS: CD Projekt

DirectX ray tracing performance (average FPS)

	RTX 3090	RTX 3080	RTX 3070	RTX 3060 Ti	RX 6900 XT	RX 6800 XT	RX 6800
3DMark Port Royal	60.8	53	37.4	32.3	45	42.8	35.4
Call of Duty: Black Ops Cold War	87.8	79.7	63.7	54.4	51.4	48.6	42
Crysis Remastered	67	62.5	52.7	43.9	55.5	46.9	40.8
Fortnite	37.8	32.5	23.4	20.3	28.2	23.4	18.9
Shadow of the Tomb Raider	104	92.4	70.4	63.1	85	79.8	68

All tests performed at 1440p ultra settings, with ray tracing enabled. Test PC consists of a Core i9-9900K, MSI MPG Z390 Ace motherboard, 2x16GB DDR4-3600 memory, and a 2TB M.2 SSD.

performance, and it may not be applicable to all RT implementations, but it does provide interesting data points. Which brings us to the final topic: Actual RT performance in currently shipping games.

RT Hardware Performance

We selected 10 graphics tests and games that use the DirectX Raytracing API and run on both AMD and Nvidia GPUs. That last point is important, because there are currently two games that use DXR and only work on AMD GPUs (*Godfall* and *The Riftbreaker*), and at least a few tests and games (*Bright Memory Infinite*, *Cyberpunk 2077*, and *Wolfenstein Youngblood*) that only work on Nvidia GPUs. Not surprisingly, each of the games is promoted by the respective GPU company, so the upcoming RT gaming wars could get messy (see table above).

Right now, it looks like Nvidia is crushing AMD in RT performance. Overall, the RTX 3070 comes in just ahead of the 6800 XT, and the 3080 is 25 percent faster than AMD's RX 6900 XT. As for the 3090, it's in a class (and price) of its own.

But then we look at *Dirt 5* and have to wonder how much vendor-specific optimisations play a role. There, the 6800 XT beats the 3080 by 8 percent. Yes, this is an AMD-promoted game, and the DXR is still in beta. Maybe Nvidia will close the gap, and to be fair the RT effects in *Dirt 5* aren't particularly impressive. As for the other games, they came out before AMD's RX 6000 series launched, which means they were optimised for Nvidia by default.

The thing to keep in mind is that AMD RDNA2 GPUs are in both the PlayStation 5 and Xbox Series S/X, which means that every console game that implements RT will be targeting AMD by default. Only time will tell how that muddies the waters.

Crysis was one of the first games to truly push the boundaries of what we could do with revolutionary new shader tech. Ray tracing is much the same.

Resolution upscaling: Getting more from less

There's still one more important aspect of ray tracing that we haven't discussed: DLSS (Deep Learning Super Sampling). RT is computationally intensive, so any way to reduce the number of rays cast is extremely helpful. RT solutions already use denoising to help improve performance, but the goal of DLSS is to reduce the number of pixels rendered from the start.

At its core, the idea of DLSS is pretty easy to grasp. Use machine learning to train a deep-learning network on how to upscale and anti-alias games. The trick is that while the training process can be incredibly time-consuming, the inference aspect – using the trained network and running it against frames in a game – is far less demanding. Across the five DLSS 2.0 games we tested, DLSS Quality mode improved performance on the RTX 3060 Ti by 65 percent at 1440p.

For games that support Nvidia's proprietary tech, Nvidia GPUs enjoy a commanding lead over AMD. Even the RTX 3060 Ti

PIC: Crytek

outperforms the RX 6800 XT by 50 percent on average in games that use the latest DLSS 2.0 implementation – and that's using the DLSS Quality mode; higher performance DLSS modes are also available.

How does it look? If you take screenshots of native rendering and DLSS rendering and compare them, sometimes DLSS looks better than native with TAA (Temporal Anti-Aliasing); other times it looks perhaps a bit worse. In motion, though, you'd be hard-pressed to tell the difference – except for the fact that DLSS runs at far more palatable frame rates.

AMD is working on an alternative to DLSS – FidelityFX Super Resolution. The thing is, DLSS 2.0 is here, support is integrated into Unreal Engine, and quite a few game developers and publishers have also jumped on the DLSS train. And why wouldn't they? RT is so demanding that even the mightiest of GPUs can struggle at higher settings, especially at higher resolutions. With all the RT options maxed out, not even the RTX 3090 can maintain 60fps in *Fortnite* – though it can with DLSS enabled.

Perhaps more important than ray tracing right now, DLSS has very tangible benefits. Games such as *Cyberpunk 2077* can even use DLSS without enabling RT, which makes 4K viable on cards like the RTX 3060 Ti. A $900 GPU, running the most anticipated game of 2020 at maxed out settings (minus RT) and 4K at 60fps? Yeah, we didn't see that coming at the start of the year. The 3060 Ti can also do maxed out RT with DLSS at 1080p and 60fps if you prefer.

Ray-traced mountains to climb

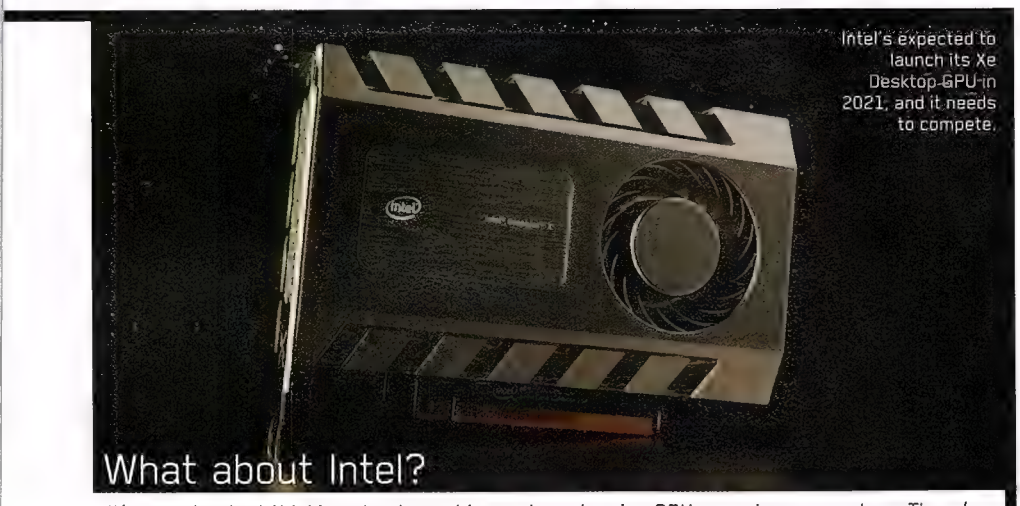
Two years on, and it's interesting to see what has changed and what hasn't. Nvidia is faster at RT, and enabling RT in most games is still a great way to tank performance for a modest improvement in visuals. But in the right situations, RT can make a big difference. There's no way to get high-quality visuals suitable for film without ray tracing or path tracing, and while games continue to improve, we're a long way off from playing anything that has visuals worthy of a summer Hollywood blockbuster.

One thing that has changed since the first RTX cards launched is the number of games with support for ray tracing. Big publishers may have been first out of the gate, but those first forays into real-time RT feel pretty lackluster compared to some of the latest games. At present, there are currently around two dozen games that use RT in some form, with many more currently in the works.

It's funny how we can get used to games looking a certain way and be happy with it, and then along comes something new and our expectations change. *Control* paved the way with a new level of visual fidelity, and *Cyberpunk 2077* now joins it, with most other games still trying to catch up. While you can certainly play either game without ray tracing, once you've spent some time running around the hallways of the Federal Bureau of Control or Night City in all their RT glory, you miss the improved reflections, lighting, and shadows once they're gone.

We remember the days of the first programmable shader GPUs, with games like *Crysis* causing hardware to physically cry out in pain at times. It took many years before that level of graphics became relatively commonplace, and ray tracing will follow the same path. We're still nowhere near the point where RT hardware has fully penetrated the market. Part of that is thanks to the rise of laptops. 12 percent of all PCs on Steam might have RT-capable GPUs, but if we're looking purely at laptops, that number will certainly be lower. Consoles getting RT hardware was probably necessary before we'd get to see the tech proliferate.

With the latest GPUs, we now have cards that are significantly faster than two years ago, and future generations will continue the upward climb. In that sense, right now we're really just trudging through the mist-shrouded foothills of ray tracing, looking up to the summit in the distance. It's going to take time to get there, but in another two or three generations of graphics hardware we'll think back fondly on our hike through the valley of rasterisation and conclude that, yes, the ray-traced panorama before us was worth the effort. ■



Intel's expected to launch its Xe Desktop GPU in 2021, and it needs to compete.

PIC: intel

What about Intel?

It's easy to start thinking about graphics and ray-tracing GPUs as a two-pony show. There's AMD on the one side and Nvidia on the other. But Intel doesn't intend to be left out, or at least that's what it claims.

For the past few years, Intel has been working its way toward releasing dedicated graphics cards. Headed by Raja Koduri, formerly of AMD's GPU division, 2021 is the year when we'll finally see the fruits of Intel's labors. There will be multiple products, ranging from low-power integrated graphics solutions to high-end gaming cards, and all the way up to data center-focused parts for supercomputers. Xe LP already exists in the latest 11th Gen Core mobile CPUs (AKA Tiger Lake), but the dedicated cards will be a different story.

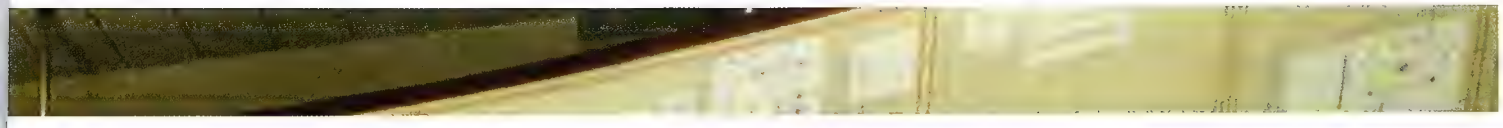
How different? That's the $64,000 question. Xe HPG stands for High Performance Graphics, and Intel should have a good idea of what it's up against. It needs to go toe to toe with AMD and Nvidia if it's going to succeed. That means more than just hardware, as drivers are important in modern graphics cards.

So far, Intel's Xe LP Graphics have been impressive for 15-25W devices, but they're nowhere near the level of performance offered by dedicated GPUs. Put more bluntly, GTX 1050 is faster, and that's a three-year-old $230 GPU. What we don't know yet is how Xe will scale up to 250-300W parts with far more computational power. We do know that Intel is planning on supporting ray tracing, both DXR and VulkanRT, with Xe HPG. Hopefully it will be fast and competitive rather than weak and late to the party.

BEATING THE BUG

Pics: Joe Traver/ getty images

The power grid at the Niagara Mohawk Power Corporation control facility in Buffalo, NY December 28, 1999, during the final phase of Y2K testing.



IAN EVENDEN DISCOVERS THE HISTORY OF A PROBLEM MANY THINK NEVER EXISTED.

There was no human sacrifice. Dogs and cats did not live together. The only mass hysteria was in the media. And unlike ***Ghostbusters***, the Millennium Bug, also known as the Y2K problem, was very real. It was only through a lot of hard work on the part of programmers and IT contractors across the world that bad things didn't happen. And it's not as if we weren't warned about it years in advance.

For those under the age of 40, here's the condensed version: as the year 2000 approached, warnings increased in the press that, at one second past midnight on January 1, all computers would experience an integer overflow; planes would fall out of the sky, and nuclear reactors explode as a result of catastrophic computer failures linked to the date rollover. This didn't happen, as most computers had been "fixed" – some properly, and others in a way that merely postponed the problem. There were effects, some detrimental and others just annoying, from a date-related integer overflow in 2000, just as there were effects from such bugs before that year. In fact, we continue to feel the effects today. Here's how Y2K unfolded...

Where it all began

First, *Oppa Gangnam Style*! The Korean pop hit that taste forgot thrust its way manfully through the eardrums of the world and racked up 2,147,483,647 views on YouTube in 2014. This particular figure was the largest number of views YouTube's backend could support back then, as the site was written with 32-bit integers in mind. A quick upgrade to 64-bit integers later, and Psy's terrifying total could continue its unstoppable upsurge toward the new ceiling of over nine quintillion views. The basic problem here, an integer overflow, is essentially the same as the Y2K problem.

It all boils down to programmers taking a shortcut, and representing a year with two digits instead of four. This happens absolutely everywhere, despite International Standard ISO 8601 specifying that dates should be written as YYYY-MM-DD. Had computers, particularly embedded systems, used this standardised date format, there wouldn't have been a problem, but computer storage space was once very expensive, and every byte counted, so many programmers used YY-MM-DD, or MM-DD-YY, or DD-MM-YY to save both space and processing time. This all worked fine for a long time, but eventually, due to the way two-digit dates were interpreted, it meant that as 1999 turned to 2000 those systems found themselves in 1900 and, unaccustomed to this time period, either failed or displayed an error.

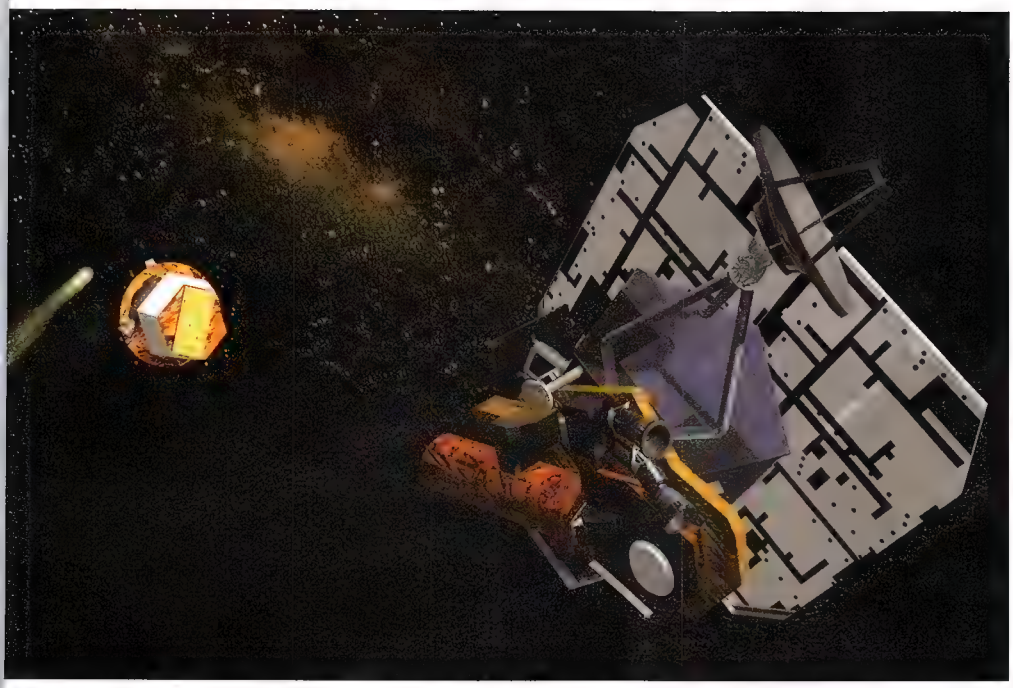
Another way to think of it is in terms of the odometer in your car. As it passes 99999.9 kilometers, the final digit clicks around and returns to 0. This causes a cascade reaction through every other digit, returning them all to the same state. It can't generate an extra decimal place, so instead of 100000.0 you get 00000.0. Your car isn't, sadly, returned to factory-fresh condition, but this mechanical wrapping-around of the numbers mirrors what happens in a computer.

Peter de Jager, host of the *Y2K: An Autobiography* podcast and a prolific public speaker on the subject, is often credited with bringing the Y2K problem to widespread attention through a 1993 article in *Computerworld* magazine, but awareness of the problem goes back further than that. IBM computer scientist Bob Bemer noticed it in 1958 while working on family tree software. In the 1970s, banks offering 30-year mortgages bumped into the problem, while in the 1980s the financial industry was forced to take notice, as bonds with expiry dates beyond the year 2000 were issued. By 1987 the New York Stock Exchange had 100 programmers working on the problem, and had spent US$25 million on it. The federal government would go on to spend US$11 billion.

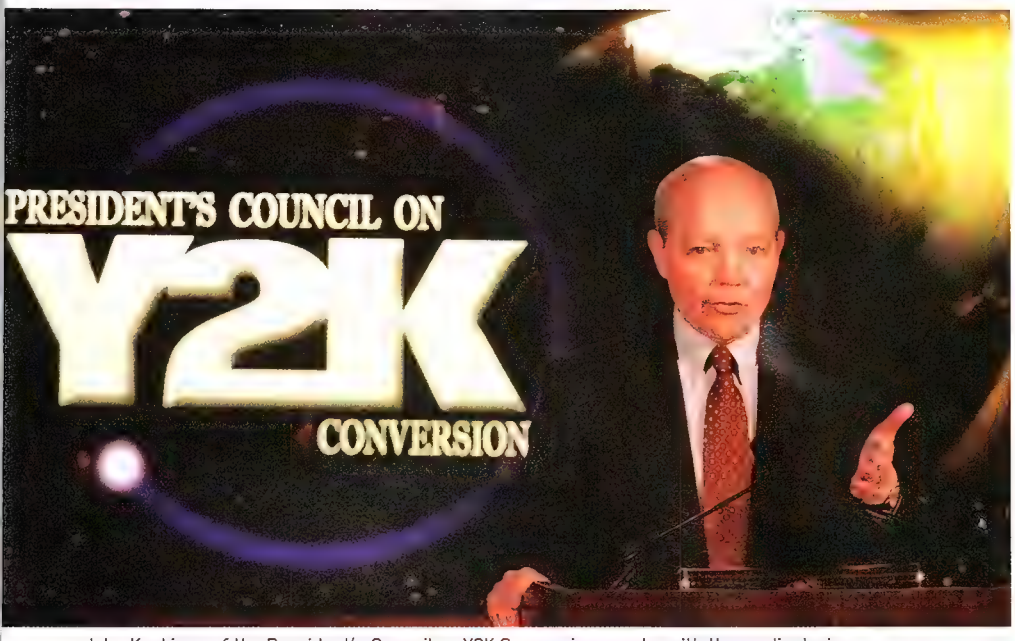
De Jager's article came about as a result of some persuasive tactics with an editor: "I was at an Association for Systems Management meeting, I think in San Francisco," he tells us. "And I'm giving a talk on something very mundane, the PC productivity paradox." This is the slowdown in productivity in the US in the 1970s and 1980s despite rapid development in IT at the time. "There were 300 or 400 people in the room, including this *Computerworld* editor. When I got home, she called me, said she liked the presentation, and asked me to do an article on it. This is back in

Employees monitor the National Command Center for Mastercard International, January 3, 2000. No Y2K problems were encountered.

Psy's *Gangnam Style* video on YouTube, showing a seriously impressive 3,931,348,435 views.



NASA's Deep Impact probe ceased communication in 2013 after its clock reached 2,147,483,647 tenths of a second since January 1, 2000, and overflowed.



John Koskinen of the President's Council on Y2K Conversion speaks with the media during a press conference in Washington, DC, February 29, 2000.

the day when print media was much larger than it is today.

The old *Computerworld* magazines were like an inch thick, and would drop on your desk every week, the Bible of the IT industry. And I said, 'You have to be kidding. You want me to write about a stupid topic like PC productivity? How about I write about the biggest problem in the IT industry that we're going to face? The fact that we store the year in two digits, and seven years from now this thing is going to go belly-up.' She says, 'Well, OK, you can do that'. It was a little bit of serendipity."

De Jager's article, titled "Doomsday 2000," was called "the information-age equivalent of the midnight ride of Paul Revere" by *The New York Times*.

The Y2K name would come two years later, in an email sent by Massachusetts programmer David Eddy in 1995: "People were calling it CDC (Century Date Change), FADL (Faulty Date Logic). There were other contenders. Y2K just came off my fingertips," Eddy told *The Baltimore Sun*.

THE 2038 PROBLEM

There are plenty more integer overflow bugs out there, and one of the most prominent involves dates stored on Unix and Unix-like operating systems. While it's fixed on most of the Unix-likes we use commonly, such as Android, macOS, and iOS (early versions of OS X are vulnerable, but the chances are they won't still be in use in 2038), embedded Unix systems like those in factories, medical systems, airplanes, or cars might be still in use – it's only 18 years, after all.

It's also a problem with things like file systems and databases, which have been written with a Unix timestamp in mind.

The problem is this: susceptible systems treat dates as a number of seconds after January 1, 1970. This figure is stored as a 32-bit integer, and the largest possible value that can be stored is 2,147,483,647. This is a lot of seconds, but runs out at 3:10:07 AM on Tuesday, January 19, 2038. After this, it will be interpreted as a negative number, or 8:45:52 PM on Friday, December 13, 1901. It then counts up again, toward zero.

There's no universal solution to this problem, beyond upgrading to a 64-bit OS or architecture. Java, for example, uses 64-bit integers to count microseconds since January 1, 1970, and won't run out of dates for almost 300 million years.

Time and date storage problems are fairly common. Owners of Boeing 787 aircraft – we know you're reading – should be aware that if you don't switch your airplane off at least once every 51 days, you'll get misleading data from it (including important things like altitude and airspeed). And there is, of course, a Year 10,000 problem too, linked to the year having five digits instead of four.

And Windows users should stop looking so smug: that OS's date range runs out in the year 30,828 – though that's plenty of time for a patch there.

Public perception

There is, as we've hinted, something of a PR problem for Y2K. 20 years on, it's viewed by some as a joke, public hysteria, or a problem conjured up by those keen to sell us new computers and never a real threat. The reality is different: "I don't know of a single person working on Y2K who thinks that they did not confront and avoid a major risk of systemic failure," said John Koskinen, chairman of President Bill Clinton's Council on Y2K, in early 2000. The then-British prime minister, Tony Blair, called it "one of the most serious problems facing not only British business but the global economy today." John Hamre, United States deputy secretary of defense, called it "the electronic equivalent of the El Niño, and there will be nasty surprises around the globe."

Others disagreed. In their book *Running Office 2000 Professional*, published in May 1999, authors Michael Halvorson and Michael Young predicted that most PC hardware and software would be unaffected. "As you learn about the year 2000 problem, and prepare for its consequences, there are a number of points we'd like you to consider," they wrote. "First, despite dire predictions, there is probably no good reason to prepare for the new millennium by holing yourself up in a mine shaft with sizable stocks of water, grain, barter goods, and ammunition. The year 2000 will not disable most computer systems, and if your personal computer was manufactured after 1996, it's likely that your hardware and systems software will require little updating or customising."

A British startup company, Greenwich Mean Time, took a different view. In 1997 it began selling a software package for £20 (equivalent to $97 today) called Check 2000, which promised to "Check 2000 flags and fix year 2000 PC problems" in "less than the time it takes to drink your coffee." It sold over 4 million copies around the world, and the company's founder, Karl Fielder, was so confident in the patch that he gave his entire staff 10 days' vacation over the millennium turnover, diverting all calls to his cell phone. He got 15.

Estimates of what the world spent on Y2K preparations vary wildly. Whole government agencies were set up, large salaries paid – you can draw parallels with many large human endeavors. And like the Moon landings or the current pandemic, it's a breeding ground for conspiracy theories.

Jerry and Carolyn Head and their children David, Lesley, and Sarah with their Y2K stockpile (generator, wood, canned goods, etc.) in preparation for possible millennium apocalypse caused by the Millennium Bug.

So what did happen?

The US Naval Observatory briefly recorded the year as 19100; 150 slot machines at racetracks in Delaware failed; credit cards with expiry dates in 2000 were rejected because they'd expired in 1900; Telecom Italia sent out bills dated 1900 for the first two months of the year; a radiation alarm system was shut down at a Japanese nuclear power station, and 15 other nuclear reactors around the world had to be shut down (not bad, considering there were 432 in operation worldwide at the time). Planes did not drop from the sky (indeed, Koskinen made sure he was flying at millennium midnight to show his confidence in the measures the US had taken), and military facilities did not burn as a result of the date change. However, the effects were still wide-ranging, despite the amount of work put in.

"The notion that there were no problems is absolutely ridiculous, says de Jager. "We had problems prior to the year 2000, and we identified problems that would have happened if we didn't take care of other problems. There's no debate about it except for people who don't understand." One point of confusion is that some, like Check 2000's customers and those who read the Office 2000 Professional book, were using PCs. Windows 98, NT4, and 2000 were robust operating systems that could be patched, and suffered minor Y2K effects involving the display of dates on screen, but little else. "Microsoft understands the critical nature of the Year 2000 issue and is committed to diligently testing its products and promptly providing information and solutions to its customers if issues arise," Rich Kaplan, director of the Platforms Infrastructure Group at Microsoft, said in a statement reported by *CNET*. "In the course of testing efforts with Windows 98, we have identified and fixed these minor Year 2000 issues." The bigger problems came from applications, specialist add-on hardware, and embedded systems that were not so easily updated.

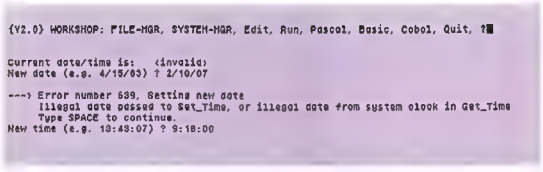
The idea that there were no issues comes, de Jager believes, from "unjustified confidence in computer systems." Y2K, in his view, brought to the fore how reliant society had become on computers. "They sort of snuck into the systems, into organisations. And while IT people knew what they were doing, the C-level executives were sort of saying, 'Yeah, there's that department down there, they're doing something with computers, they seem to be doing it okay, but it's no big deal. And they didn't really

realise how much their organisations were depending upon those computers.

"We had to come to them and say, 'Oh, by the way, that stuff that you're depending upon that you don't really understand how much you depend upon? It's all going to go belly-up real soon, and we need to fix it. Could we have US$20 million please?' We have an unjustified confidence in our computer systems. Our computer systems are incredibly vulnerable. IT people know this is no secret, but the people who pay for the IT and depend upon it weren't really aware of this until Y2K made people aware."

De Jager saw his goal, at the time, as not being to fix the problem, but to get people to accept the problem existed. "If I'm speaking to an audience, and the overwhelming response is 'He's a nutter, he's absolutely off his head, and I'm going to go back and test our systems and I'm going to prove that he's a charlatan,' then my work has been done. Organisations did go back. They went to their banking systems and they advanced the date on a couple of files, and then they ran their system and the whole thing crashed. Boom. And they went, 'Crap, he's right.'"

Another issue was the assumption that older systems, running older code written in older programming languages whose programmers were, alas, getting older, would be replaced long before the integer overflow became a problem. We've all heard rumors of financial institutions that have built their IT systems on creaking foundations laid down in the 1980s, but could it be more than rumor? "I absolutely guarantee it," says de Jager. "In the US government in many of the states, their payroll systems and their unemployment systems are in COBOL."


{V2.0} WORKSHOP: FILE-MGR, SYSTEM-MGR, Edit, Run, Pascal, Basic, Cobol, Quit, ?
Current date/time is: (invalid)
New date (e.g. 4/15/83) ? 2/10/07
---> Error number 639, Setting new date
Illegal date passed to Set_Time, or illegal date from system clock in Get_Time
Type SPACE to continue.
New time (e.g. 13:43:07) ? 9:18:00

Above: An Apple Lisa, a computer released in 1983, returns an error when asked to accept a date beyond January 1, 2000.

Left: Pope Gregory XIII, the man to blame for the Gregorian calendar system we use today. He came up with it in 1582 after errors in the Julian calendar had caused it to drift by 10 days.

COBOL is a programming language that first appeared in 1959, but has been thoroughly and regularly updated through 2014. "There's nothing fundamentally wrong with COBOL, there really isn't," says de Jager. "It's a good product, but it wasn't designed to handle, you know, 20 million people seeking unemployment. These systems are just dying, and dying because they weren't designed to handle that many records. They can make changes to it, but you're just perpetuating the problem. What you really need to do is to go through the old COBOL systems and rewrite and redesign the systems.

"There are Fortran (from 1957, last stable release 2018) programs out there too, I guarantee it. These languages don't die. They sort of continue on in the background. They are immortal."

Finding people who still speak these languages to maintain the systems isn't the way forward, he says. "The real way to solve it is to bite the bullet. Recognise that these things have expiry dates, not because they get bad, but because better solutions come along."

This solution isn't always popular, because of its cost and the length of time it takes to implement. Of course, de Jager has an opinion about this: "People don't realise how expensive this stuff is," he says. "Especially when everything depends upon it. When your entire organisation is depending upon 50,000 programs written in an arcane language, replacing it is not an overnight task. It takes four or five years. We have examples of payroll systems that need to be replaced all over the world. In New Zealand, they tried to replace the teachers' payroll system, and teachers didn't get paid for a year. In Canada we have something called the Phoenix system, which is supposed to replace all the huge payroll systems for the government, and we're still having trouble with that." Indeed, Canada's Standing Senate Committee on National Finance

WAS THE YEAR 2000 A LEAP YEAR?

Leap years, in which an extra day is inserted at the end of February, come every four years, right? Not so fast. The Gregorian calendar is a bit more complicated than that.

In order to qualify for the extra day, a year needs to be evenly divisible by four. But if it's divisible by 100, it's not a leap year. However, if you can divide it by 400, it is again. This is because the Earth's rotation around the Sun is ever so slightly less than 365.25 days, and over the course of 400 years, you end up with three extra days if you have a leap year every four years. The year 2000, therefore, was a leap year, but 2010 wasn't. And nor was 1900.

That is, unless you use Microsoft Excel. The venerable spreadsheet app incorrectly treats 1900 as a leap year, justifying it as a matter of backwards compatibility with the even more venerable Lotus 1-2-3, which contained the same error.

Fixes for this leap year problem tended to get bundled in with Y2K date fixes, but at other times, the incorrect calculation of leap years, or the failure to accept that they even exist, has caused issues. Witness the freezing of first-generation Zune 30 models on December 31, 2008, though they fixed themselves 24 hours later. In 1996, all 660 computers controlling two aluminum smelting plants in Australia and New Zealand shut down at midnight on December 31, as they couldn't handle a year with 366 days. Sony's PlayStation 3 consoles thought that 2010 was a leap year, which caused errors on March 1 that year. Gmail's chat system, meanwhile, sent all chat records saved on February 29, 2012 back in time to December 31, 1969, and the same year, Microsoft Azure was taken offline on February 28 due to incorrect time calculations.

called Phoenix an "international embarrassment" in a 2018 report.

"We don't really appreciate how complicated this stuff is," de Jager says. "We think we'll just do it. You know, here's a couple of million dollars, just take care of it. It's not that easy."

It's not over yet

And the way Y2K was fixed may come back to haunt us in the future. A technique called "windowing" was often used, where instead of rewriting computer code to allow for four-digit years, it was instead modified so that dates within a specific window – for example 00-20 – were recognised as beginning with 20, and all others with 19. This method kicked the can down the road, setting another hard deadline by which time it was assumed that the devices would have been replaced. Guess what?

"We saw Y2K problems occur in 2020, and we could make that prediction because we knew that the problem wasn't fixed," says de Jager. "It was pushed to the future instead of expanding to four-digit years. What we did was, we used things like windowing, and one of the windows that we used was 20 years. It'll certainly rear its head again in 2025, again in 2030, and 2050, because those were all the dates used for windowing."

Known 2020 glitches included WWE 2K20, a bafflingly popular wrestling videogame that became non-functional until a patch was pushed out; cash registers that were manufactured by Novitus stopped being able to print receipts until fixed; and yet more utility companies produced bills dated 1920.

The year 2020 was often picked for windowing for a reason: Unix. The operating system that just won't die, Unix originated at Bell Labs in 1969. It lurks in things like

LESSONS ON COOPERATION

We spoke with the president and CEO of the EastWest Institute, Bruce McConnell. McConnell served for four years as deputy under secretary for cybersecurity at the US Department of Homeland Security, and led the International Y2K Cooperation Center (IY2KCC) as its director for the UN and the World Bank.

APC: How did you become the director of the IY2KCC?
Bruce McConnell: In mid-1998 I was serving as the chief of information and technology policy in the US Office of Management and Budget. Y2K preparedness of the US government departments and agencies was a principal focus of my office's activity. The president had recently appointed a "Y2K Czar," John Koskinen, who was responsible for coordinating all US preparations. As John got into the issue, he realized that Y2K was a problem that would not respect national boundaries. Working with the United Nations and the World Bank, John and his UK counterpart organized governmental contributions to the World Bank that, along with funding from other countries, created the IY2KCC… the White House seconded me to stand up and run the organisation, where I served until we closed down in March 2000.

APC: What did the IY2KCC achieve?
BM: The IY2KCC did not solve the Y2K problem; it made the work of those who were solving it more efficient and effective. We did so by establishing a global community of people working to remediate the Y2K bug, representing 159 countries and organized along regional and sectoral lines. These subcommunities shared knowledge about what devices were vulnerable to failure and which were not, and about techniques that worked to remediate them. For example, there was concern that elevators might malfunction and drop to the ground. A team based in Germany and Japan investigated elevator control systems and found that only one high-end Japanese system had vulnerability, and that the vulnerability would not cause the elevator to drop, only to stop functioning. We helped the team disseminate this information on a global basis and saved a lot of people time to work on other… vulnerabilities.

Our regional communities were quite successful in identifying interconnections, such as power grids, between neighboring countries. For example, the Latin American group produced the first-ever coordinated map of high-voltage transmission lines in South America, which enhanced cooperation on Y2K, and later, on other power reliability work…

In September 1999, we correctly predicted that the consequences of the bug were likely to be modest. As that report noted, the key issue at that point had become avoiding panic, i.e., reassuring the public that all the work that people around the world had done was sufficient to limit the impact, and that there would be no major crisis. Our work contributed to maintaining a general calm around the crisis, at least for most people.

APC: What would have happened if action had not been taken?
BM: The most serious vulnerabilities were to be found in financial systems. Many governmental and private sector financial systems, including taxation systems, stock markets, and banking transfer systems, had been among the first efforts [of] large-scale computerisation. With software code dating from as far back as the 1970s, many of these systems relied on two-digit dates and… calculations about how much time had elapsed between two dates. Further, the code was often poorly documented and no one actually knew how everything interacted, making the possible impacts difficult to predict.

Without remediation, it was likely that major systems which business and governments depend on to make the global economy function would fail in various ways, either by shutting down, or, possibly worse, by providing unreliable results. In either case, public loss of confidence could have wreaked economic havoc and social unrest.

An example of long-term impact can be found after 9-11. The New York Stock Exchange had developed testing scenarios to validate the functionality of its core systems. When the exchange was closed because of the World Trade Center attack and associate[d] damage in lower Manhattan, the operators brought up the backup site, and used the Y2K testing suites to validate functionality. If those suites had not already been developed, the market would have been done for weeks…

APC: What can be learned from Y2K?
BM: The principal lesson is that, faced with a global threat that cuts across national boundaries and involves every sector of the economy, a successful way of proceeding is to create a loosely-coordinated, cross-disciplinary, global community of people who want to solve the problem, and then facilitate their working together. The IY2KCC worked with all global powers through the United Nations. One can imagine if such a mechanism had been established a year ago, perhaps with the cooperation of major powers and the World Health Organisation, we might be in a better place than we are today.

Android and macOS, and counts time in a particular way related to seconds since January 1, 1970 (see boxout, p58), and the year 2020 is exactly 50 years after 1970. Again, no "fixed" systems were expected to still be in operation by the time 2020 came around, and the executives who ordered such cost-cutting didn't expect to still be in their roles when it came back to bite them either.

Our society still hasn't come to terms with its reliance on computers. We tend to think that, if they all disappeared tomorrow, everything would be okay. The truth is that computer failures kill people – look at Boeing's 737 Max airliner, grounded worldwide after 346 people died in two crashes caused by automated flight-control malfunctions. If we hadn't done anything about Y2K, then the consequences could have been disastrous. "There's no way to know," he says. "We knew things would go wrong, but there's no way to predict with any certainty what could go wrong."

Former *CNN* science editor Kevin Sanders, writing in *The Nation* in February 1999 was prepared to go there, however: "The greatest danger comes from Russian and Chinese missiles," he wrote. "As the Y2K digital tsunami moves west from the international date line in the Pacific, China and Russia will become the first nuclear nations to face possible computer failures – almost half a day earlier than the United States. All contact and communications could be lost or disrupted. Launch-site commanders could be left literally in the dark, trying to read the meaning of silence."

The article continues: "According to a number of Russian scientists currently working in the United States, the financially starved Russian military and its dilapidated computer systems are even more prone to Y2K failure than those in the United States... Sergei Fradkov, a former Soviet satellite control technician now working for a Wall Street software developer [says], "Russia is extremely vulnerable to the Year 2000 problem... If the date shifts to 0 for a brief moment... that fools the system into thinking there is a high probability of an attack in progress."

At that time, Russian and Chinese nukes were no longer targeted at US cities, but this didn't stop the speculation: "[T]hey can be back on target in ten seconds. Whether this could happen as the result of an automatic or accidental computer default is not known." Everything in the US was A-OK, however; Captain Allan Toole, head of the Pentagon's Y2K Special Weapons Agency, was quoted in the same article, saying, "I have a good feeling about Y2K in this agency." So that's all right then.

In July 1996, Senator Daniel Patrick Moynihan wrote to Pesident Bill Clinton. "The computer has been a blessing," he wrote. "If we don't act quickly, however, it could become the curse of the age... each line of computer code needs to be analysed and either passed on or be rewritten." That effectively did happen, whether it was a long-term fix, an emergency patch after problems developed, or windowing that pushed the problem to the future.

Legions of IT professionals stepped up to squash the bug, millions of home users installed patches, and its worst effects were mitigated. And this is something that rings through to the present day, and transcends the narrow world of computing: when we all work together, we can move mountains. ■

MODERN-DAY PARALLELS

"When people used to say that Y2K was a hoax, it used to annoy me," says de Jager. "Now I just laugh. It's like people saying that COVID doesn't exist.

"I've been watching COVID right from the start, been watching the curves, and this is all about curves. This is all about epidemiology and how things move. If you don't change the conditions, that curve will continue to do what that curve is doing, you know. 4,000 people died yesterday, yeah, and you're gonna see 4,000 people today and for the next 20 days.

"People do not respect science. For one thing, they don't understand it because our education systems have failed everybody. And we have people, you know, believing the Earth is flat, and COVID doesn't exist, and it's all a myth, and that masks don't work.

"There were two things with Y2K that worked to our advantage. One, the message was pretty consistent. Yes, we had some outliers saying it wasn't real. We had a lot of reporters and journalists who didn't know anything about systems saying this was nonsense. And you can sort of discard them because they weren't having any influence on the people actually out there fixing the problem. Two, there was a freaking deadline. A date that we had to get this thing done by. And that really concentrated our efforts.

Bottom left: Missile Commanders confirm a launch warning over the phone during a practice drill at the North America Aerospace Defense Command (NORAD) Cheyenne Mountain Complex in Colorado Springs, Colorado, November 9, 1999, in the run-up to the new millennium.

Bottom right: Console grapplefest *WWE 2K20* had a buggy launch in 2019, but stopped working completely once 2020 actually rolled around.

PC BUILDER

WHAT'S HAPPENING IN THE AUSTRALIAN PC MARKET

System news

Half a Jigawatt!? Is crypto mining going too far? Mark Williams looks at the relationship between the graphics card drought and mining boom.

When Nvidia announced the RTX 3000 Laptop series of GPUs at CES we all got a little excited about the new performance levels that would come in this year's laptops. Since being out for a couple of weeks and getting mildly annoyed at Nvidia, with its continued terrible mobile GPU naming scheme, we find that getting any laptop with an RTX 3000 series GPU in it is next to impossible.

Aside from the usual suspects of production yields at Samsung, and the COVID pandemic driving up the demand as people stay at home and want higher-powered gaming systems, the mining boom has reared its ugly head and is hitting new heights, with one Bitcoin now worth over $65,000 (almost triple the 2017 boom price); miners simply cannot get enough GPUs to mine with.

With the desktop market tapped out, mining farms are bulk-buying new laptops with RTX 3000 GPUs in them to grow their hashing clusters.

Given the pandemic and the mining boom, an internet café in Vietnam, after closing its doors to the public due to local COVID restrictions, turned to crypto mining and has since found that "profits are higher" than doing regular business.

Of course, running a lot of power-hungry GPUs consumes a lot of electricity and works against a farm's profitability. One sneaky operator in Malaysia was caught and arrested for illegally tapping into the electricity grid to get free power for their mining operation.

Even legal large-scale mining farms have their own power issues,

MARK WILLIAMS
Mark is an IT professional with a strong interest in voiding warranties.

with 14 large mining farms in Iran (where electricity is cheap and is thus a favourite place for miners to set up shop) causing power outages. Those four farms alone consume up to 450 Megawatts, typically enough for a city of 100,000 people!

The mining craze will likely last quite a while; most analysts have written off the first half of this year as far as GPU supplies go. Nvidia has even stated that in Q1 of 2021 RTX 3000 card stock levels are likely to get even worse before improving. With the likes of Elon Musk and Tesla buying US$1.5B worth of Bitcoin recently, it seems like the market isn't going to cool down any time soon.

However there has been some small glimmers of hope recently. The first being that the US government is set to act on the global chip shortages.

U.S. President Joe Biden's administration has stated that it "will identify 'choke points' in the current supply chain and figure out a way to relieve bottlenecks in the system that have been present for years – bottlenecks that have been exacerbated by the current pandemic. The administration is actively working alongside key stakeholders in the industry and with our trading partners to do more now".

President Biden is set to sign an executive order in the coming weeks that will begin a supply chain review for critical goods, including the semiconductors that power consumer electronics, helping to establish ways of "improving the physical production of those items in the U.S.".

Something SMIC (a large semiconductor foundry based in the US) will be looking forward to, since the former Trump administration's import restrictions prevented it from acquiring more of the advanced equipment it needed to increase production to meet global chip demand.

Nvidia is also set to return back to the future as rumours abound that Nvidia is about to re-release – at least in limited quantities – RTX 2060, 2060 Super and GTX 1050 Ti cards. With no new GPU launched in the lower part of the market yet this generation, it seems Nvidia has dug up some spare stock from the back of its closet to try and help satiate intense market demand.

How long this will all last is anyone's guess; lets just hope that the coming RTX 3060 (non-Ti) launch provides enough stock, so that gamers can actually get a hold of something to game with. ■

Shop talk

How are you finding the supply of RTX 3000 laptops currently?

RICHARD, AFTERSHOCK PC:
"30-series laptop supply at the moment is very low for us. We have had orders in for months and so far, we're just getting a trickle of those coming in. Our demand for them at the moment far outstrips the units we are able to get our hands on. We are hoping that more of our backorders start to arrive over the next few weeks and months, which is what has been indicated to us from the factories." ■

Market snapshot

A sampling of PC systems available this month.

$5,899 | tinyurl.com/APC492UM

GX INTEL i9-10900K RTX3090 24GB

If you're looking for the ultimate in gaming performance, you needn't look much further than this system. With Intel's fastest processor – that's ripe for overclocking thanks to the 360mm liquid cooler – this system will rock in just about every scenario, whether productivity or gaming.

The RTX 3090 is the current graphics king, be it for 4K gaming or high refresh rates. The extra side fan on this model is quite neat, designed to push air directly over the MOSFETs on the card.

The power supply and storage are both expected in this price bracket, however the RAM is a tad lacklustre. with no RGB and just a 2400MHz speed rating. Spending a few extra dollars at checkout for a faster and/or larger capacity kit might be worth considering.

CPU: Intel i9-10900K **Cooler:** Deepcool Gamerstorm Castle 360RGB V2; **Motherboard:** Gigabyte Z490 AORUS ELITE AC **Graphics:** Inno3D RTX 3090 Ichill X4 24GB; **Memory:** 16GB DD4 2400MHz; **Storage:** 1TB M.2 NVMe SSD; **Power Supply:** Corsair HX850; **Case:** Asus TUF Gaming GT501 White

$4,749 | tinyurl.com/APC492JW

JW Computers GMR Arc 6800XT

This white-out build is for those looking for the best gaming performance, but not wanting to spend the further 20 percent to get to the very best. The Ryzen 5800X is perfect for heavy gamers as it offers all the cores you could need while having them all located on one CCD, meaning no inter-CPU communication latency hits. It's a little pricier than it should be, but it is using a golden sample CCD, as also found in 5950X processors.

The Radeon 6800XT offers almost RTX 3080 levels of performance – meaning high refresh rates at 1440p and even the chops for 4K gaming thanks to the 16GB of VRAM. The 32GB of RAM is more than ample and makes this system border on workstation levels of system resources for those that like to dabble with productivity work. A fine system for any enthusiast.

CPU: AMD Ryzen 7 5800X **Cooler**: Asus ROG Strix LC 360 RGB White**Motherboard:** MSI X570 Tomahawk WiFi **Graphics:** AMD Radeon RX 6800 XT **Memory:** Corsair Vengeance RGB Pro 32GB DDR4 3200MHz **Storage:** Samsung 970 EVO Plus 1TB NVMe M.2 SSD **Power Supply:** Corsair RM750X **Case:** Asus ROG Strix Helios white

$2,599 | tinyurl.com/APC492AC

Austin Computers A22 Gaming Planet

Aiming squarely at the sweet spot for price and performance, this relatively affordable rig offers up oodles of performance at a reasonable price point. The CPU is great for most gaming scenarios and the paired RTX 3060 Ti is more than competent for running high detailed 1440p games at over 60fps or 1080p games at over 100fps.

A spot-on RAM kit and a reasonable SSD plus HDD combination offer solid capacities and speeds for this price bracket. Despite this rig being mostly on point for its goal, the air cooler for the CPU, while adequate and flashy, isn't very performant when hit with extreme loadings, so don't expect much overclocking headroom with the included cooler. Perfect for competitive gamers or those looking for their first serious gaming rig.

CPU: Intel Core i5-10600KF **Cooler:** Thermaltake UX100 ARGB **Motherboard:** MSI MAG B460 Tomahawk **Graphics:** MSI GeForce RTX 3060 Ti Gaming X Trio **Memory:** 16GB Kingston HyperX Fury DDR4 3200MHz **Storage:** Kingston A2000 M.2 500GB SSD, Western Digital WD Blue 2TB HDD **Power Supply:** Cooler Master MWE White 650W **Case:** MSI MAG Vampiric 010X

$7,999 | tinyurl.com/APC492SC

Scorptec MSI MEG Aegis Ti5

Putting the striking visuals aside, for the internal parts included this system are awfully expensive. You really need to be an MSI or *Tron* fan to want to buy this as similar specced PCs can be had for almost one third less in price.

The case features a multifunctional knob front and centre which allows you to set RGB modes, game modes, launch games, display information plus much more, and is all customisable via MSI's Dragon Center software. Neat!

The 128GB of RAM is certainly the most unique spec in this system; not something you'll commonly see in gaming systems. Quite a waste for gaming though, so be sure you'll actually need that much when considering this system.

CPU: Intel i7-10900K **Cooler:** MSI 240mm AIO **Motherboard:** MSI Z490 based **Graphics**: RTX 3080 **Memory:** 128GB DDR4 2933MHz **Storage:** 2TB M.2 PCIE SSD, 3TB HDD **Power Supply:** 750W **Case:** MSI MEG Aegis Ti5

BLUEPRINTS

VALUE- AND PERFORMANCE-DRIVEN HYPOTHETICAL BUILDS

PC BUILDER

Budget

Competent.

This has been one of the most difficult times to talk about hardware, especially when it comes to pricing up builds. Shortages, scalpers, and miners have put a strain on this industry, and many of our parts saw price rises. So, we've made several changes to the Budget builds this month to keep prices reasonable, and with these extensive changes to that build, we've managed to come up with a saving of $125 compared to last month. Not bad! But for that we've lost access to eight PCIe graphics lanes (so we'd be running 8x PCIe 3.0 instead of 16x PCIe 4.0 for the GPU), two cores, four threads, and we have 25 percent of the L3 cache we did have, and no access to PCIe 4.0 either.

However, we've kept the motherboard's chipset the same, so if stock does come back we should be able to upgrade that processor to a Ryzen 3 3100 at a later date, but it's actually really difficult for us to recommend buying this build right now. If you need a PC, and we mean desperately need a budget PC, then this is a good recommendation. But honestly, hang tight and hopefully by winter things will have worked themselves out.

Sadly it's a similar affair for Intel too, although we've managed to dodge some of the more radical hardware changes that our AMD build has suffered. We've had to swap the Core i3-10100 to the F variant, so we lose integrated graphics, and we've managed to grab a 1660 GPU. A lot of the components are identical between these two rigs this issue, mostly because they're just the cheapest we could get our hands on in a vain attempt to mitigate price increases.

AMD INGREDIENTS

PART		PRICE
CASE	CORSAIR 4000D AIRFLOW	$130
PSU	450W EVGA 450 BR 80+ BRONZE	$70
M/BOARD	ASROCK B450M-HDV R4.0 M-ATX2 **NEW**	$95
CPU	AMD ATHLON 3000G **NEW**	$95
GPU	GIGABYTE GEFORCE GTX 1660 6GB **NEW**	$370
RAM	16GB (2 X 8GB) ADATA XPG D60 @ 3000 MHZ **NEW**	$130
SSD	250GB SAMSUNG 980 PRO M.2 PCIE 4.0	$130
HDD	1TB SEAGATE BARRACUDA 1TB 7200 HDD **NEW**	$70
OS	WINDOWS 10 HOME 64-BIT OEM	$60
PRICE:		**$1,150**

INTEL INGREDIENTS

PART		PRICE
CASE	CORSAIR 4000D AIRFLOW	$130
PSU	450W EVGA 450 BR 80+ BRONZE **NEW**	$70
M/BOARD	MSI B460M-A PRO MICRO-ATX	$130
CPU	INTEL CORE I3-10100F **NEW**	$135
GPU	GIGABYTE GEFORCE GTX 1660 6GB **NEW**	$370
RAM	16GB (2 X 8GB) ADATA XPG D60 @ 3000 MHZ **NEW**	$130
SSD	500GB SAMSUNG 970 EVO M.2 PCIE 3.0 SSD	$100
HDD	1TB SEAGATE BARRACUDA 1TB 7200 HDD **NEW**	$70
OS	WINDOWS 10 HOME 64-BIT OEM	$60
PRICE:		**$1,195**

PC BUILDER

Mid-range

Decent.

So, we came into this thinking we wouldn't really change many parts this time around because of the way stock is right now, but inevitably that feels like a betrayal, so we're trying to minimise cost where we can. However, it's proving difficult to avoid, especially if you want to keep performance the same.

Fortunately, across both AMD and Intel, at least at the moment, neither CPU has seen a substantial price increase – no doubt because Intel's about to release new processors, and these are last-gen AMD chips, so there's stock floating around. The memory, GPU, and motherboard, on the other hand, most certainly have. In fact, the AMD 5700 XT GPU we used in our AMD build just a month ago has skyrocketed from $700 up to an incredible $1,000. That's $1,000 for a mid-range, last-gen 1080/1440p graphics card. It's saddening. We found this Asus RTX 2060 for around $700, which is still way too much for a GPU of that caliber. Overall, we're $46 up on last issue for our AMD build.

And then we get to the Intel build. To be fair, this is mostly self-inflicted; we swapped out the motherboard to something more at the budget end of the spectrum, but we decided to plump for the same Asus GeForce RTX 2060 Super that's in the AMD build. It's the cheapest RTX 2060 Super we could find, and it's definitely an upgrade on last issue's 1660 Super. It has approximately 32 percent more performance at 1080p Ultra.

And so again we end up with the same conclusion: it's just not the right time to buy a system, or even consider upgrading. Scalpers, miners, and stock shortages are pummelling the market into submission, and you'd be far better off waiting it out, as much as that saddens us to say. It's not only modern-gen components that are getting hit hard here, but every element of the industry.

AMD INGREDIENTS

PART		PRICE
CASE	LIAN LI PC011-DYNAMIC	$210
PSU	550W CORSAIR RMX (2018) 80+ GOLD **NEW**	$140
M/BOARD	ASUS TUF GAMING X570-PLUS	$330
CPU	AMD RYZEN 5 3600	$320
COOLER	240MM CORSAIR H100X AIO **NEW**	$140
GPU	ASUS GEFORCE RTX 2060 DUAL OC MINI **NEW**	$710
RAM	16GB (2 X 8GB) CORSAIR VENGEANCE LPX DDR4 @ 3600 **NEW**	$125
SSD	500GB SABRENT ROCKET 4.0 M.2 PCIE 4.0 **NEW**	$210
HDD	1TB SEAGATE BARRACUDA 1TB 7200 HDD **NEW**	$70
OS	WINDOWS 10 HOME 64-BIT OEM	$60
PRICE:		$2,305

INTEL INGREDIENTS

PART		PRICE
CASE	LIAN LI PC011-DYNAMIC	$210
PSU	650W EVGA SUPERNOVA GA 80+ GOLD **NEW**	$160
M/BOARD	ASROCK Z490 PHANTOM GAMING 4/2.5G **NEW**	$200
CPU	INTEL CORE I7-10700	$450
COOLER	COOLER MASTER MASTERLIQUID ML240L AIO	$100
GPU	ASUS GEFORCE RTX 2060 DUAL OC MINI **NEW**	$700
RAM	16GB (2 X 8GB) G.SKILL AEGIS 16GB @ 2400 **NEW**	$100
SSD	500GB WD BLACK SN750 M.2 PCIE 3.0	$140
HDD	1TB SEAGATE BARRACUDA 1TB 7200 HDD **NEW**	$70
OS	WINDOWS 10 HOME 64-BIT OEM	$60
PRICE:		$2,240

PC BUILDER

Turbo

Stupendous.

Predictably, this issue's Turbo builds have been just as rough as the others. You can no longer buy an AMD Ryzen 9 5900X at the time of writing, and the 5950X is well into four figures at this point, so we've had to take a step down and grab the Ryzen 7 5800X instead. We've managed to save $60 compared to last issue with the 5900X, although we've lost four cores and eight threads as well. But then there's literally no alternative there. We've also rejigged things a bit with the motherboard and the power supply to save some cash here too.

Inevitably, we get to the graphics card situation once more, and this applies to both builds. Similar to just a few issues back, there's just no stock anywhere, of anything, so we've had to realign our sights with an Asus GeForce RTX 2080 Super. It's in stock at the time of writing, too, which is extra nice.

All in all, we've managed to keep the price increases down on the AMD Turbo build. We've lost the performance of the RTX 3080, and the four additional cores from the Ryzen 9 5900X, but as a result of these movements have come up with a respectable overall decrease from last month's build, which is a win.

In the case of Intel, things are similar. We managed to keep the price down below last month's Intel build, even with the jump up in GPU. However, everything else has remained resolutely in stock. Without a doubt, those latest Ryzen processors are superior to their Intel counterparts, but it means little if they aren't in stock.

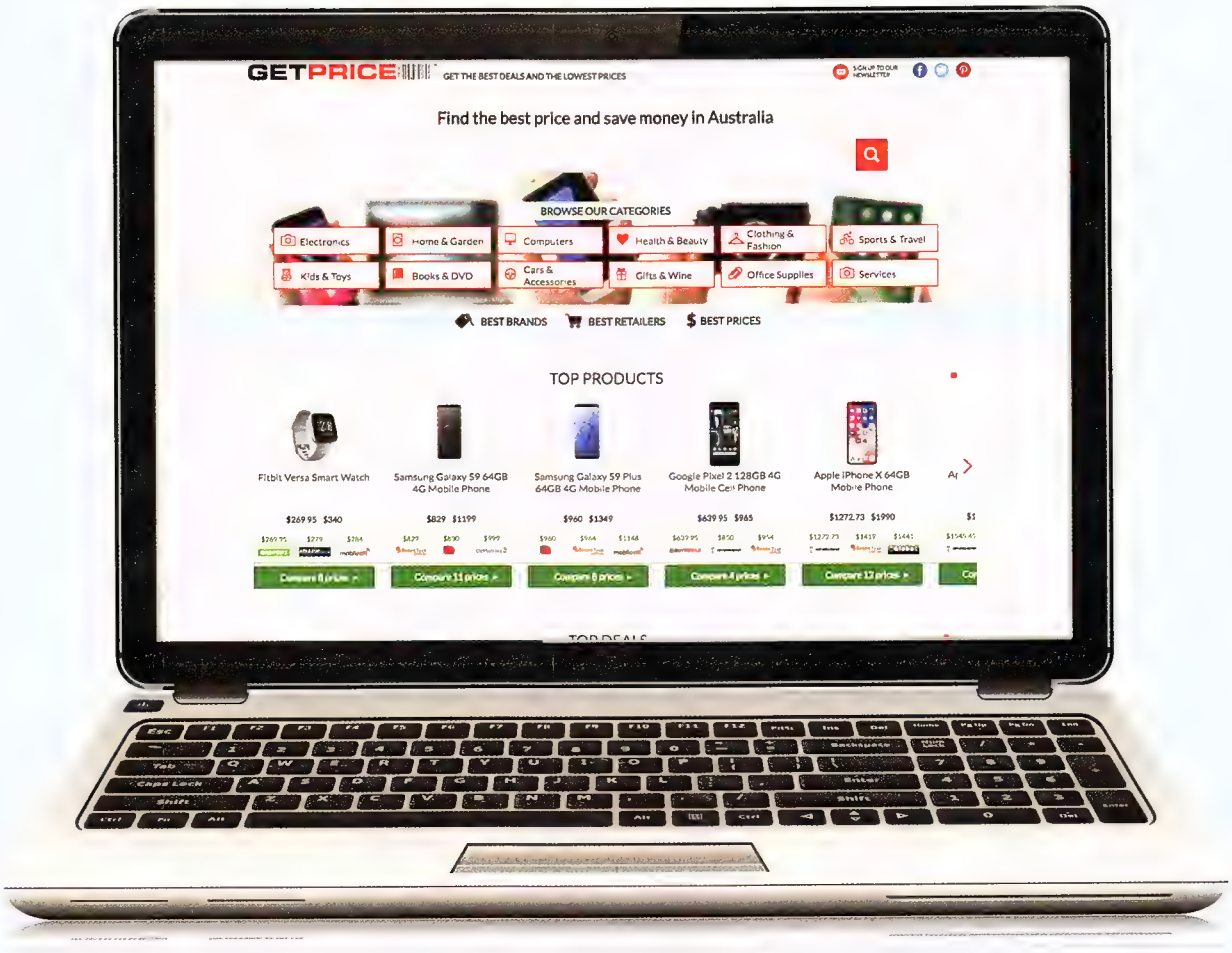
Our best advice right now? If you are looking to invest a little and tinker with things, we'd recommend taking a look at your case, aesthetics, lighting, and cooling. All of these are very much in stock, and at normal prices, so you can have fun reducing your noise levels, overclocking your parts, or brightening up your build.

AMD INGREDIENTS

PART		PRICE
CASE	PHANTEKS ENTHOO PRO 2 TEMPERED GLASS	$220
PSU	750W CORSAIR RM750X (2018) 80+ GOLD **NEW**	$200
M/BOARD	MSI MPG X570 GAMING PLUS **NEW**	$270
CPU	AMD RYZEN 7 5800X **NEW**	$800
COOLER	CORSAIR ICUE H150I ELITE CAPELLIX 360MM AIO	$300
GPU	ASUS GEFORCE RTX 2080 SUPER DUAL EVO 8GB V2 **NEW**	$1,249
RAM	32GB (2 X 16GB) KINGSTON HYPERX FURY DDR4 @ 3600 MHZ **NEW**	$240
SSD	1TB GIGABYTE AORUS GEN4 M.2 PCIE 4.0	$280
HDD	6TB WESTERN DIGITAL BLUE HDD **NEW**	$260
OS	WINDOWS 10 HOME 64-BIT OEM	$60
PRICE:		$3,879

INTEL INGREDIENTS

PART		PRICE
CASE	PHANTEKS ENTHOO PRO 2 TEMPERED GLASS	$220
PSU	750W CORSAIR RM750X (2018) 80+ GOLD **NEW**	$120
M/BOARD	ASUS TUF GAMING Z490-PLUS **NEW**	$360
CPU	INTEL CORE I9-10900K	$700
COOLER	NZXT KRAKEN X73 360MM	$300
GPU	ASUS GEFORCE RTX 2080 SUPER DUAL EVO 8GB V2 **NEW**	$1,249
RAM	32GB (2 X 16GB) KINGSTON HYPERX FURY DDR4 @ 3600 MHZ **NEW**	$240
SSD	1TB CORSAIR MP400 M.2 PCIE 3.0 SSD	$220
HDD	6TB WESTERN DIGITAL BLUE HDD **NEW**	$220
OS	WINDOWS 10 HOME 64-BIT OEM	$60
PRICE:		$3,729



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BUILD IT

The Ultimate 4K Gaming Rig

Zak Storey attempts to capture that great white whale of PC gaming.

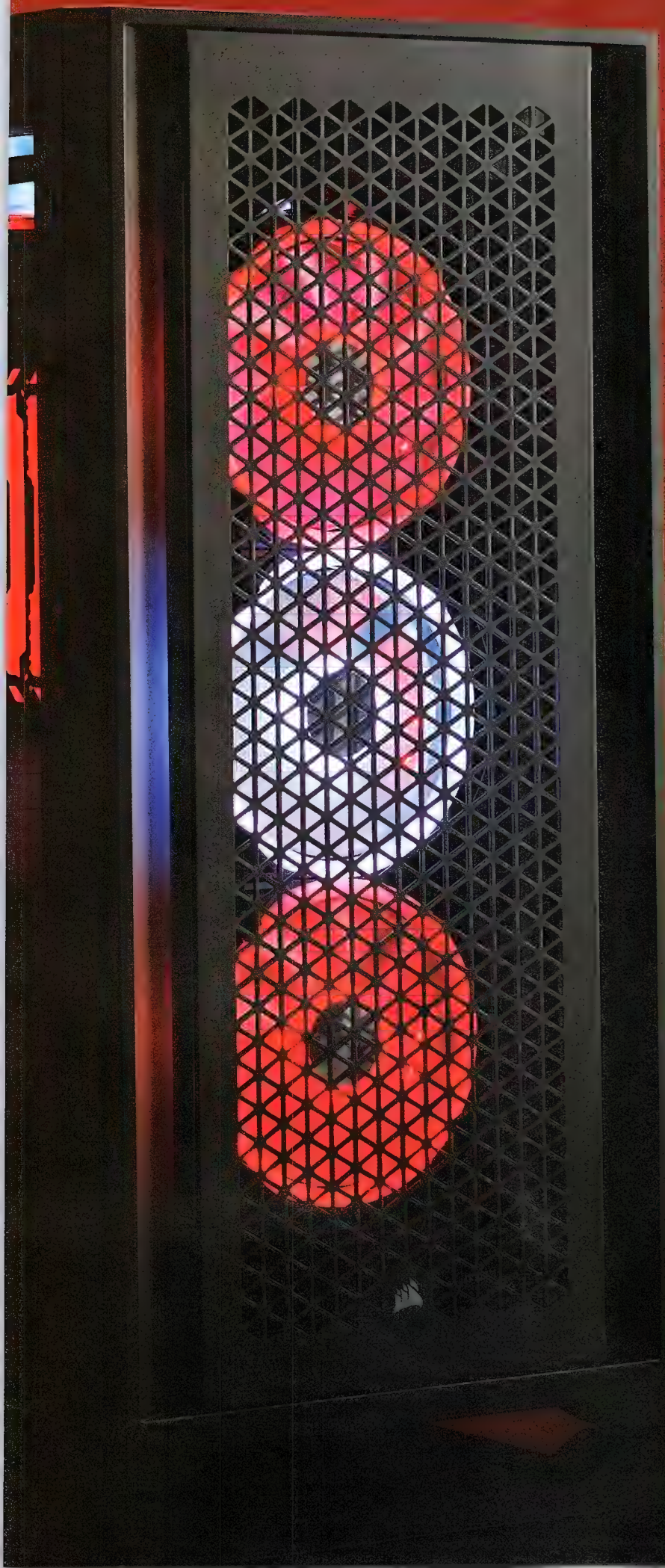
It's that almost mythical thing – as gentle as a whisper, and just as fragile. We move one step closer each and every year, and yet it seemingly moves one step further away every time we approach it.

4K gaming is something we've written about for many years at *APC*, and something that has never come to fruition – at least, not in the way we want it to. Why is that? Well, just as much as technology advances, processors get more efficient, and graphics cards render an ever greater number of frames, so to do graphics improve, code gets denser, and more modern effects come into play to imitate real life, requiring more processing power.

If the question was "Are the games of 2016 playable at 4K today at 60fps?" we could happily say "Yeah, with ease" – and yet that's not the aim. We are human, and because of that, we constantly strive for more. It's in our very nature and is the driving force in our society.

This hunt for gaming excellence leads to better technologies that worm their way into every facet of our existence: better graphics cards, more powerful processors, and faster memory and storage affect everything from video rendering and 3D modelling to tailored medicine, protein folding, and more. Without this multi-billion dollar industry we would undoubtedly be worse off as a species.

And so, we're once again hunting for that mythical white whale. The aim is simple: 4K gaming at frame rates that are as high as we can muster, on a budget that is far more reasonable than it was in the past. Is this the moment we finally see 4K overtake HD and QHD as our main resolution? Let's find out.



INGREDIENTS

PART		PRICE
CPU	AMD RYZEN 9 5950X	$1,250
GPU	AMD RADEON RX 6800 XT 16GB	$1,500
RAM	64GB (4X8GB) CORSAIR VENGEANCE RGB PRO @ 3200 CL16	$500
M	ASUS ROG CROSSHAIR VIII DARK HERO	$850
OS STORAGE	1TB CORSAIR FORCE MP600 M.2 PCIE 4.0	$280
SECONDARY STORAGE	2TB CORSAIR MP400 M.2 PCIE 3.0 SSD	$400
PSU	750W CORSAIR CXF750 80+ BRONZE	$140
CABLES	CORSAIR PRO PSU CABLE KIT TYPE 4 GEN 4 - RED	$150
COOLER	CORSAIR ICUE H150I ELITE CAPELLIX AIO	$300
FANS	2X CORSAIR ICUE QL120 FANS 3-PACK	$450
CASE	CORSAIR 5000D AIRFLOW	$230
TOTAL		$6,050

Prices correct at time of printing. Street prices used.

CPU | $1,250

AMD Ryzen 9 5950X

Right now this is the king of all processors. AMD has dominated the field with its Ryzen 5000-series chips, and at the top of the stack is the Ryzen 9 5950X. Coming in at a hefty $1,250, this thing packs 16 cores, 32 threads, and a max clock speed of 4.9GHz, with DDR4 support up to 3,200 MHz (although 3,600/3,733 still remains the best for maximum core complex performance).

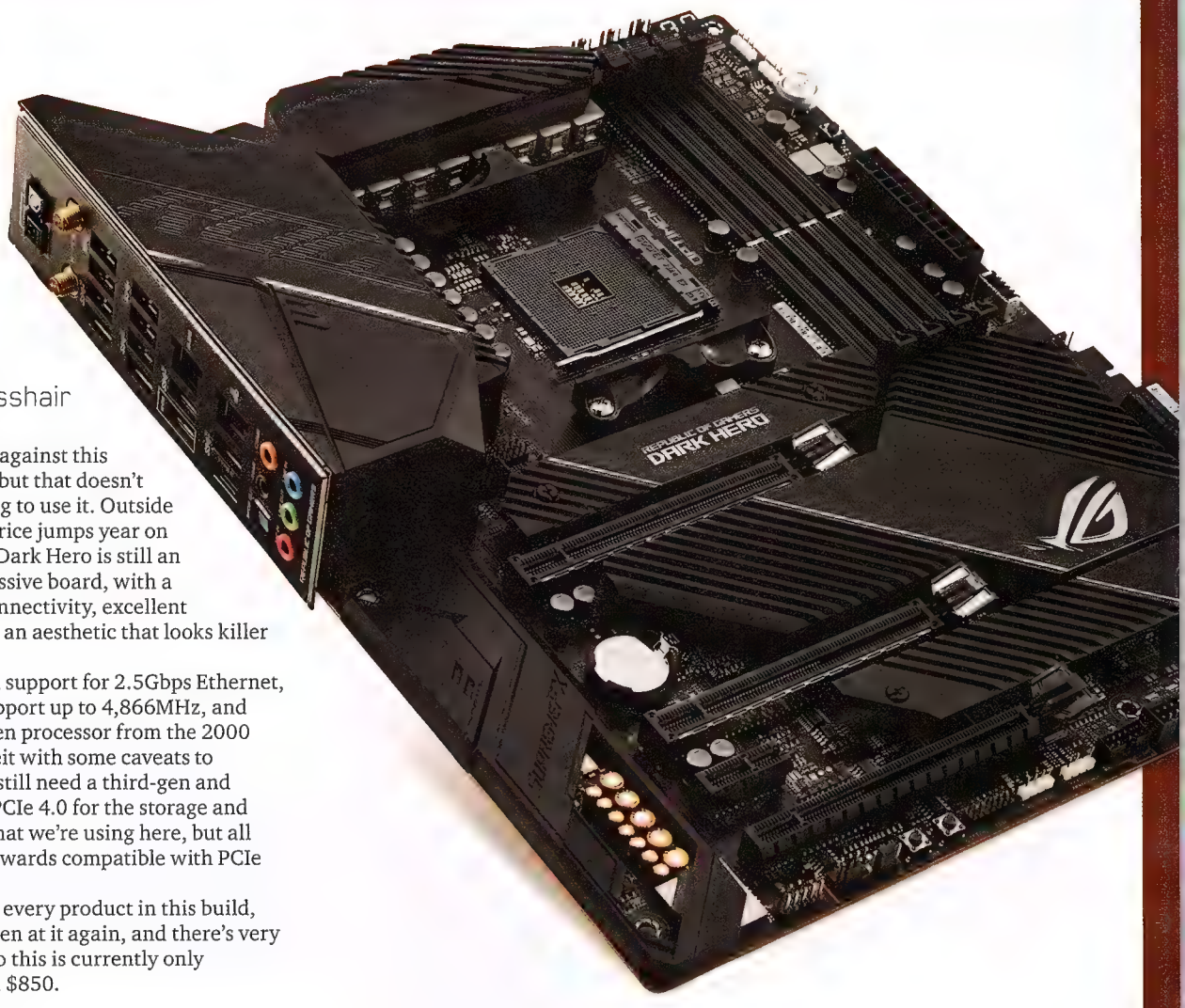
Along with its recalibrated 64MB of shared L3 cache and 8MB of L2 cache, this 7nm behemoth packs some of the best single-core performance in the business, achieving a massive 652 points in Cinebench R20's single-core test. Compare that to Intel's best, the Core i9-10900K, at 533, and it's 22 percent faster. The only things faster than it in multi-core scenarios are Ryzen Threadripper 3960Xs and above. It's an insane amount of performance for a consumer desktop part – at least if you can find one in stock, and not at that ridiculous 50-percent markup we're seeing today.

GPU | $1,500

AMD Radeon RX 6800 XT 16GB

The new kid on the block, AMD's Radeon RX 6800 XT may not quite be at the top of the Red GPU stack compared to our CPU of choice, but it's darn close, and comes packing 72 of AMD's latest RDNA2 compute units, 4,608 stream processors, and a grand total of 26.8 billion transistors. On top of that it boosts up to an impressive 2,250MHz at max load. That's not too shabby. Pair that with 16GB of GDDR6 on a 256-bit bus, and we're onto a scorching-hot card that's hopefully more than capable of powering all of the latest titles at 4K 60fps, if not much higher.

The downsides? Well it's a power-eater for sure, with a rated TDP of 300W. The cooler design itself features some red accents, so it can be difficult to colour-coordinate your system. Oh, and it's not in stock anywhere, really. And if it is, it's 129 percent its original price thanks to scalpers.



MOTHERBOARD | $850

Asus ROG Crosshair VIII Dark Hero

We may have railed against this product in the past, but that doesn't mean we're not going to use it. Outside of those increased price jumps year on year, the Asus ROG Dark Hero is still an exceptionally impressive board, with a fantastic array of connectivity, excellent power-delivery, and an aesthetic that looks killer in the flesh.

It also comes with support for 2.5Gbps Ethernet, Wi-Fi 6, memory support up to 4,866MHz, and can handle any Ryzen processor from the 2000 series onwards, albeit with some caveats to connectivity. You'll still need a third-gen and above for access to PCIe 4.0 for the storage and graphics solutions that we're using here, but all these ports are backwards compatible with PCIe 3.0 devices.

Sadly, like almost every product in this build, the scalpers have been at it again, and there's very little stock online, so this is currently only available for around $850.

RAM | $500

64GB (4x8GB) Corsair Vengeance RGB Pro @ 3200 CL16

If you've had a cursory glance at this feature's opening spread, you'll notice that this thing is illuminated to the hilt with RGB lighting. We're leaning on Corsair a heck of a lot to get this build all black, white, and red – those traditional PC gaming colours.

To that end, we've also borrowed some of the memory from one of our older builds, the Data Scientist rig. We've grabbed 64GB of the stuff straight from the computational powerhouse, as it comes complete with a 3,200MHz frequency, and a C16 latency rating, making it ideal for our 4K gaming aspirations. There's certainly no chance we'll be throttling on memory here, that's for sure. We're not too worried about it not hitting that 3,600/3,733MHz sweet spot – in our testing, performance gains on that front tended to be within the 1-3 percent margin, and not worth the extra cash on an already expensive product due to stock shortages.

OS STORAGE | $280

1TB Corsair Force MP600 M.2 PCIe 4.0 SSD

We can't build a killer 4K gaming PC without upping the ante when it comes to storage. Across our system we're taking advantage of M.2 PCIe devices, with one of our most used drives at this point, the Corsair Force MP600 M.2 PCIe 4.0 SSD. Utilising the Phison E16 controller, this thing tops out at 4,950MB/s sequential read, and 4,250MB/s sequential write. It also features a five-year warranty, support for AES 256-bit encryption, and an impressive 1,800 TBW (terabytes written) endurance rating.

It's also worth noting that the latest Corsair Force MP600 Pro has just been announced at the time of writing. So if you can, pick up one of those instead, as it ups those sequential figures all the way to 7,000MB/s for both read and write speeds. Is that necessary for gaming?

Probably not, but it's the only product on our list that hasn't been hit by mass shortages and price scalping, and if you fancy working on any non-gaming projects, then a nippy OS drive will help.

SECONDARY STORAGE | $400

2TB Corsair MP400 M.2 PCIe 3.0 SSD

Our drive of choice for our secondary storage is the Corsair MP400. This is what QLC drives should have been to begin with. Although it's not as rapid as some of its SLC brethren, Corsair's MP400 packs in an impressive warranty, alongside solid sequential performance for small file transfers, making it ideal for game and media storage. This is in part due to its large dynamic write cache, and it'll happily top out at 3,480MB/s sequential read, and 1,880MB/s for a good 250GBs before falling off that cache cliff in the writes. Considering that a lot of the data you'll be moving is a lot smaller than that, you shouldn't run into trouble.

The cache does recover somewhat quickly (our reviewer tells us, usually within 30-40 minutes), but let's be fair, this is a 2TB drive for $400, making it one of the best-value SSDs on the market right now, and thankfully not a product that's massively out of stock anywhere.

PSU & CABLES | $140

750W Corsair CXF750 80+ Bronze & Corsair Pro PSU + Cable Kit Type 4 Gen 4 - Red

We're keeping things simple with our power supply setup. It's an 80+ Bronze, 750W affair. That should be more than enough for our system – we expect at max load this thing will draw about 600W from the wall, at least according to PC Part Picker. It's worth mentioning in regards to those figures that these are worst-case synthetic scenarios. It's highly unlikely you'll be in a situation where both the CPU and the GPU are at max load simultaneously, as one will inevitably bottleneck the other. As such, even 600W is pushing it really. However, it is right on that sweet-spot for 80-percent efficiency.

The CXF comes with an RGB fan as standard, and we've paired it with a set of Corsair's Red Pro cables to make that Radeon GPU pop.

COOLING | $300

Corsair iCUE H150i Elite Capellix AIO & 6x + Corsair iCUE QL120 fans

For cooling, we're again leaning on that big Californian giant in the form of the H150i Elite Capellix cooler. Generally speaking you can get away with a 240mm AIO for the Ryzen 9 5950X, but we want to make sure we've got enough headroom to play with if we decide to go down the overclocking route in the future. We might need to keep an eye on the PSU if that's the case. We're also big fans of Capellix LEDs, so the H150i Elite is a no brainer, although it is a rather expensive cooling combo.

We've also got two sets of Corsair QL120 triple-fan packs. These each come with an RGB commander module to connect six of them together and control them via iCUE.

CASE | $230

Corsair 5000D Airflow

And last but by no means least, we have our chassis of choice for this build, the Corsair 5000D Airflow. The bigger brother of our budget favorite, the 4000D Airflow, the 5000D expands on those newly introduced design decisions found in this latest generation, and comes with a ton of hardware support, including E-ATX motherboards, vertical GPUs, push-pull rad configurations, and side-mounted radiators. On top of that, it also features those small touches to the aesthetic design that the 4000D has as well.

What's more impressive is the price – at around $230 it's nothing short of awesome, and follows a very similar vein to the 4000D. It also has its spin-off variants, including a solid-panel version (the 5000D), an RGB glass variant (5000X), and of course is available in black or white as well.

The Lucid Dream

Mythical, beautiful, luminous. Take a look at our castle in the sky.

In Jarred's Tech Talk this issue (see page 19), he went into great detail about the shortages we're seeing in the industry right now. Thanks to a multitude of different factors, the world of computing is fragmented in terms of stock, and it's only snowballing further. There's a massive disconnect between the RRP and the actual price you can buy these components for now, and it's all due to demand far outstripping supply, with some unscrupulous agents in the middle to boot.

We live in unprecedented times, and in a world so connected to its technology, especially for enthusiasts, professionals, and hobbyists like ourselves, we're suffering because of it. That's why we continue to publish the current street price you could theoretically buy the parts for today.

LENGTH OF TIME: 1-2 hours
LEVEL OF DIFFICULTY: easy to medium

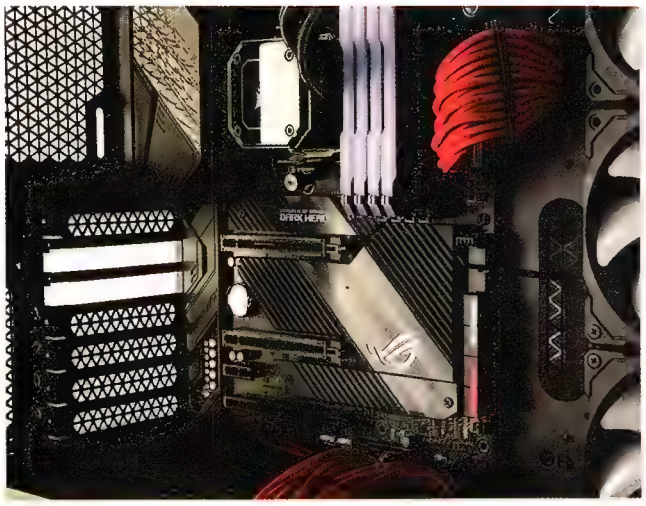
Now let's just start by saying this: do not buy this today at its current price. Encouraging scalpers only leads to more of it happening in the future, further driving up costs for us all and putting what are meant to be affordable parts way out of reach of the everyday enthusiast. What we're looking at here is an example of what can be built and achieved when stock finally comes back into existence again – something that should hopefully occur by this summer.

This build's also a bit of a special one for us, for a number of reasons. You'll also notice that there's a ton of Corsair stuff in the build too. Corsair sent us the 5000D Airflow long before the NDA was due to lift. In fact, the whole idea was that we'd have this killers AMD build ready, colour-coordinated, and illuminated in the mag, right on time for the case's NDA to drop. If you work in print media, let us assure you, meeting an NDA is like gold-dust, and something we almost always pursue. Obviously, that didn't quite go to plan, but that's not stopping us from putting this epic build together for this issue.

This time around, again due to that pesky pandemic, we're going to show you some of our favorite highlights from this system, what considerations we made, and how we put the whole thing together. It's a bit more unorthodox than our usual builds. COVID is also having an effect in our workplace, when we have a need to be there and aren't working from home, and we don't occupy the same room as our tech-savvy photographer while we actually do the build.

So let's go through this 4K gaming build, take a look at this awesome system, and explain how we forged every element of it.

"There's a massive disconnect between the RRP and the actual price you can buy these components for now, and it's all due to demand far outstripping supply."



01 DOING THINGS DIFFERENTLY

Corsair's 5000D Airflow is a behemoth. It's not quite full-tower level, but it's much larger than the 4000D mid-tower case. This is in part thanks to its ridiculous amount of compatibility for cooling components. Inside you'll find a cable-tidy bar, cable grommets, full-length PSU cover, vertical PCIe mounts, push-pull support in the roof, plenty of ventilation, and cable-management features in the rear. There's even support for side-mounted radiators.

We removed the front panel, the roof, the two dust filters, and the cable-tidy bar. We knew we were going to be installing fans on the side of the chassis (because, well, it looks cool). The cable bar is attached via four Phillips-head screws in the back of the chassis. We pulled out the 3.5-inch hard drive cage as well, to give us extra room to mount the power supply and tidy up the cables.

Motherboard installation went swimmingly. We installed four sticks of our DDR4 here, routed the cable kit in, and installed our AIO, a painless procedure with AMD as it doesn't require a special backplate.

02 AIO & MEMORY WOES

There's nothing better out there right now for brightness than a Capellix LED. On the pump block itself, you can change the colour of this to white, instead of black. Effectively, the top is a clear block with the Corsair logo engraved onto it, and the part below is a translucent acrylic. Theoretically you can remove the lot, and 3D-print your own cover if you want. One thing that did annoy us, however, is the fact that there's no easy way of routing the pump cables from the motherboard block out the top of the case. Usually we tuck these out of the way, or under a heatsink, but there's just nowhere to hide it.

At this point in time, we've had to drop down to two memory sticks to get it to boot. This gives us 32GB total DDR4 at 3,200MHz, instead of the 64GB we wanted. Effectively the motherboard wouldn't cycle, and we just ended up with a light informing us of a DRAM error and a blank screen. Remove two sticks, no problem. Place them back in, problem. This is likely due to an early BIOS on the Dark Hero having issue with our high-density memory from Corsair and Ryzen 5000 chips, and we're still trying to get to the bottom of it.

"There's no easy way of routing the pump cables from the motherboard block out the top of the case. Usually we tuck these out of the way, or under a heatsink, but there's just nowhere to hide it."

03 M.2 SLOT #1

Installing an M.2 drive is, at this point, easier than installing a 2.5-inch SSD in our eyes. There's fewer cables, less fuss, and it looks a lot cleaner – and that's before you consider the performance gains you get from it. At this point you can get standard SSDs as M.2 drives as well, but honestly, we're not even sure that it's worth doing these days. After all, an Intel 665P or Crucial P2 1TB M.2 PCIe 3.0 SSD will set you back roughly between $120-150, both of which feature speeds that are four to five times faster than the best SATA 2.5-inch or M.2 SATA SSD you can find.

In our case, installing the Corsair Force MP600 was as easy as pie. Simply undo the two Phillips-head screws, lift off the M.2 heatsink, install the M.2 drive, making sure to note where the notch is on the socket and the drive itself, take the film off the heatsink thermal pad, place it carefully back down, and resecure those two screws. There's nothing to worry about here – no LED screens or anything along those lines, just one proficient heatsink to get the job done.

04 RGB CONNECTIVITY?

Our second M.2, the Force MP400, has gone in here, in an almost identical manner. Simply undo the two screws, lift up the heatsink, remove the LAIRD film from the thermal pad, insert M.2, rinse, repeat, and you're done – no cables, no fuss, no massive drives taking up space and introducing rogue heat elements. You can also spot that we've filled both of the USB 2.0 headers on this motherboard. One of these runs to the Corsair Commander module that comes with the H150i Elite Capellix cooler, and the other runs to one of the RGB modules that comes with the QL fans.

What's particularly nice about this setup is that it doesn't rely on any RGB headers on the motherboard. Everything plugs in or is connected via the two commander units. For those who've played around with RGB before, you'll know that the software itself is inherently a nightmare to use. Multiple components from different manufacturers each require their own RGB software, and each one intrinsically seems to cause conflicts with those other programs. Even in this case, just using Asus and Corsair as our two manufacturers can lead to issues. In most cases we recommend not installing Asus's ROG Aura software, and just installing Corsair's iCUE and using that to control the lot to avoid any conflicts. Also, because we're not using any RGB headers, our two USB hubs have full control over the nine RGB fans and the pump, minimising any potential problems.lines, just one proficient heatsink to get the job done.

05 DOING THINGS DIFFERENTLY

With our GPU installed, this system's starting to look like a real monster by this point. The 6800 XT is a chunky card, but we have one major issue with it, and weirdly it's the reason this build is themed the way it is: the red accents that run all the way around the card.

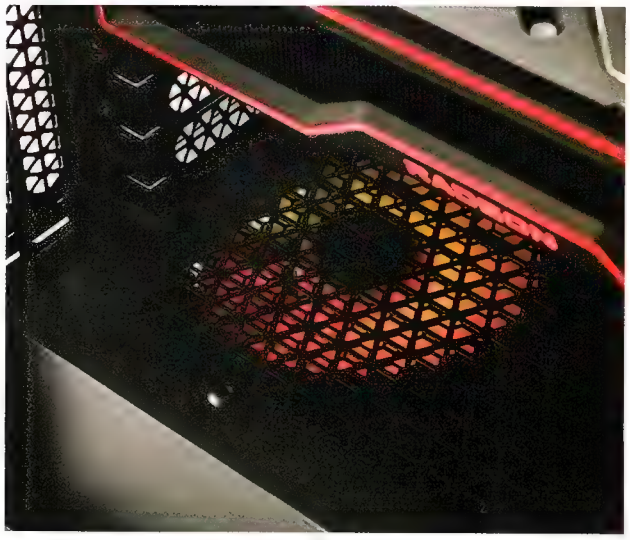
We live in a digital RGB, multi-coloured world now, where we can set lights to do any and all sorts of colours and patterns. Even Razer has dropped its famous green in favor of letting the end user choose what colour they want. So why on Earth does this reference design still insist on having that red accenting?

Anyway! Like most GPUs it's a cinch to install. Remove the two PCIe covers from the rear (thankfully it's still a two-slot card), line it up with the port, slot it into place, secure it with the two thumbscrews you removed earlier, and then install your cables. The 5000D doesn't have a direct cable cutout below the GPU, but you can run them from the back near the front I/O headers fairly easily. We quite like this flowy look we've got going on here.

06 ILLUMINATED POWER SUPPLIES

We've used the CFX RGB power supply from Corsair. It connects via a cable directly to a Corsair Commander unit for its lighting. However, we couldn't get it to register with iCUE on our first attempt or during the photoshoot, though after a quick firmware update at home during testing it was up and running. It's not a bad power supply, but it does raise questions as to whether it's worth having lighting there. To get the most out of it, you need to have the fan facing upward in a chassis like this. You could have it facing downward to get a soft underglow, but it'd be very muted.

The problem with having the fan facing upward is twofold. Firstly, if you do have a leak with the AIO, or if you're running a custom loop, if any coolant leaks into the power supply, it's kaput. On top of that, if the fan's facing down, it's typically got a mesh cover. It pulls cool air from outside the bottom of the case, through a mesh-filtered grille, and pushes hot air out the back. But with the fan facing up, it's drawing in unfiltered warm air from inside the chassis, and spitting that out the back instead. That's technically good for your other components, as you've got one extra exhaust, but less so for your power supply.



07 SIDE-MOUNTED RADIATOR?

When we saw that you could side-mount a radiator here, we went for it, because that's what it's all about when it comes to testing cases like this. Corsair advises that you install your AIO either in the roof (to allow for push-pull configs), or the front, but we wanted to try sideways. It fits quite well, and gives us a bit of a different angle compared to most other builds in towers like this.

One thing that was slightly annoying, however, was installing the front fans. This isn't necessarily something that's mission-critical or performance impacting, but the front fans, when mounted in the lowest most position, don't line up with the fans on the radiator. We raised the radiator up as much as we could to try and line these up, and got close. It's not the end of the world, but if you've got an obsession with precision, it might not be ideal.

The QL fans, although expensive, are impressive to look at – both the lighting and the rear of these things look good. In fact, despite the ones with the iCUE H150i Elite cooler looking good too, we'd have preferred a third set of QLs.

08 PANEL GAPS

We mentioned installing push-pull configurations earlier with this case in the roof, and here's a really good example of just how easy that is to do. We've removed the top panel in this shot to give you a good idea. You can see that there's a magnetic mesh filter over the top of that, but you can remove this and install an additional set of three 120mm fans, then a radiator underneath, with three more fans equipped, without contacting the motherboard at all. That way you can provide even more airflow and static pressure if you so desire.

We typically haven't seen a huge amount of benefit to running push-pull in radiators. Generally, the industry consensus is that it's not a huge deal. As long as you've got a solid amount of air going over radiators, the limiting factor as far as thermals are concerned is going to be surface area and the radiator's thermal capacity, which isn't something you can usually get around by adding more fans. That said, the gap is very good for standard airflow reasons – the less restriction you have in the way of those fans, the better they're going to be at exhausting hot air out of the top of the case.

09 REAR CABLE MANAGEMENT

And here we have the rear of the 5000D Airflow. You can see the cutout for the radiator on the left, the fan cables we have littered everywhere, and the multiple fan controllers. The case comes with a standard fan controller that plugs directly into a PWM header on the motherboard, and can support up to six fans directly. However, it only controls fan speed, not RGB. We're using that to control all of the QL120 case fans – the three in the roof, and the three in the front of the chassis.

The AIO is entirely controlled by the Corsair Commander module that comes with the cooler. We mounted that to the back of the motherboard tray using double-sided adhesive pads that Corsair provided. Theoretically that supports up to six fans, with six RGB headers, and is controlled directly via the iCUE software. However, to keep things simple, we kept all of the AIO fans on the Commander, the QL120 case fans on the integrated fan controller that came with the chassis, and the QL120 case fan's RGB on a separate controller that came with the QL fans (but doesn't control fan speed). Confused? Us too. But it works, and only requires nine fans, three controllers, and 18 separate cables (19 with the PSU).

01 FLOWING GPU CABLES
This was generally one of the few happy accidents we had with this build; having the cables here flowing like this, instead of stretched up through a passthrough or to the side, genuinely looks epic.

02 CLEARANCE & AIOS
As you can see, there's plenty of space to install a radiator along with a set of fans, and the mounting location is slightly offset too, so no problems there. However, it is slightly frustrating when it comes to that AIO pump cable running along the top.

03 DOWNLOAD MORE RAM?
We had to have two sticks of memory sadly for the shoot – we're still waiting on Asus to get back to us with a BIOS update to hopefully get the set of four working. But for the time being, 32GB at 3,200MHz is the name of the game.

04 CABLE KIT
Corsair's Pro cable kit is a nice solution to the basic black cables that come with the CXF RGB power supply. However, the cable combs leave a lot to be desired, and sadly still don't hold a candle to CableMod sets. Still, they're considerably cheaper and accent our build well.

05 ILLUMINATION
The QL fans look incredible. Combined with the Capellix LED in the AIO and the Vengeance memory, it looks impressive. The only things that are a bit of a letdown? The stock fans that come with the H150i, and the lighting in the motherboard itself (that ROG logo is actually illuminated, though you can't tell).

06 CABLE TIDY COVER
If side-mounted radiators and fans aren't quite right for you and your next build, then the Corsair 5000D in its standard configuration actually features a classy cable-tidy bar here that hides the lot, and gives you plenty of room to install E-ATX motherboards as well.

And there you have it, one ship-shape 4K gaming PC powered entirely by AMD. We've been wanting to do one of these builds for a while now, just to see what the added benefits are in the real world when it comes to AMD's Smart Access Memory tech.

For those that don't know, when using AMD Ryzen 5000 CPUs (and now 3000-series processors), with a Radeon 6000-series card and appropriate motherboard BIOS (X570 chipset), you can enable Smart Access Memory. This basically gives the processor complete access to the GPU's VRAM.

Traditionally your processor can only ever access up to 256MB of that VRAM at any one time, regardless of how much VRAM the card actually has. The CPU then uses that VRAM as a frame buffer to store information regarding the upcoming frames that the GPU has to render. In this case it could be textures, colour values, and so on. Obviously, having a limit of only being able to access 256MB at a time acts as a considerable bottleneck, so the way AMD has got around this is by using the extra bandwidth available from PCIe 4.0 and a few driver tweaks to give the processor unlimited access to the GPU's VRAM.

It's worth pointing out that AMD hasn't patented this, and it's not something that's going to stay only with Team Red. In fact, the company is actively working with Nvidia to get its cards operating in a similar manner with Ryzen processors, and even cooperating with Intel to ensure that Radeon cards work with Intel chips in the same way. Nvidia has also announced that it's working on its own variant of this technology. AMD has stated that this can lead to up to 16-percent performance increases across select titles.

In our testing we found that to be generous. On the whole we saw average improvements of around five to six percent across our testing suite at 4K, compared to it being turned off. That's nothing to be sniffed at, and free performance is free performance. It's likely, as games further advance over the next few years, that developers will be able to take better advantage of the frame buffer because of these improvements, so it could make a serious difference in future titles.

There she blows

When it came to the actual build process, well it was relatively plain sailing. The only problem we had was something we encountered with the original 4000D, and that's the position of the thumb screws that you need to remove to release the hard drive caddy. They face upwards into the chassis, yet are underneath the power supply cover, and because of that, and the fact they're overtightened during the manufacturing process, they're a nightmare to get out. We ended up using a very long screwdriver and precariously slotting it through one of the cable cutouts near the front I/O headers to get access to it, to loosen them off until we could turn them by hand.

Outside of that it all went swimmingly: the motherboard went in as easy as pie, and mounting the fans didn't present any difficulties. Being unable to perfectly align those side radiator fans with the front case fans was annoying, but not something that would keep us up at night, and cable management could've been a doddle if we'd have taken our time (there's plenty of cable-routing channels, cable covers, and Velcro straps included). It's just a seamless experience building in this thing, and when you get to the end you're left with an exceptionally clean-looking rig. One thing to point out is that if you do go for the vertical GPU route, you'll need to think a bit about how to route the PCIe power cables, as there's no direct PSU cover cutout/passthrough for them.

And the performance? Well, this thing is a beast when it comes to our testing suite. We're comparing this against our Razer Tomahawk ITX build, complete with Core i5-10600K, 64GB of DDR4, and an RTX 2080 Super, to see what it'd be like as a complete upgrade from generation to generation. Unsurprisingly, in the processing department that poor Core i5 is murdered, with the 5950X baring its teeth with a 201-percent performance increase in the multi-core test (and a 30-percent performance increase in single-core tests). PCIe 4.0 SSDs are also markedly faster, topping out near the 5GB/s mark, and on the whole traditional graphical rasterisation shows anywhere between a 31and 57-percent increase in average frame rates at 4K.

We don't currently have any ray-tracing titles in our system test suite (we're still waiting for office access for the full setups we discussed last year), but we ran 3DMark's Port Royal ray-tracing benchmark across the two rigs to give us a good idea of what's going on. And even there we're seeing a 34-percent improvement over the RTX 2080 Super. That's still shy of what you'd get from an RTX 3080, but it does slightly edge out the similarly priced RTX 3070. It's worth bearing in mind that this is a purely synthetic benchmark and isn't indicative of what you'll see in games featuring the new tech.

So, for roughly $1,500 more (at RRP) compared to our 2080 Super build, this system leaps over its predecessor. The only title currently not above 60fps is the latest *Assassin's Creed*, and even that averaged 54fps, which is far from unplayable.

It seems that we're finally starting to cusp over that 4K edge. Perhaps not this generation, but next time 4K may finally become the norm, and we can say goodbye to 1440p.

APC LABS BENCHMARKS

Indicates best result

	Cinebench R15 Multi	CrystalDisk QD32 Sequential	CrystalDisk QD32 Sequential	Middle Earth: Shadow of War	Total War: Warhammer II	Shadow of the Tomb Raider	Red Dead Redemption II	Assassin's Creed Valhalla
	Index	Read MB/s	Write MB/s	FPS	FPS	FPS	FPS	FPS
Gaming Rig	1,421	4,985	4,199	72	65	80	69	54
Zero-point	1,421	3,534	3,170	55	47	57	44	38

Our zero point consists of an Intel Core i5-10600K, 64GB of DDR4 @ 3600, a Zotac GeForce RTX 2080 Super AMP Extreme, and a 2TB Samsung 970 Evo Plus M.2 PCIe 3.0 SSD. All tests were performed at 4K on the highest graphical profile available.

QUICK TIPS

Sound driver lag. Power problem. Driver updates.

The *APC* team tackle problems across the spectrum of devices and software. Learn a new trick or fix you can use.

Update Windows Media

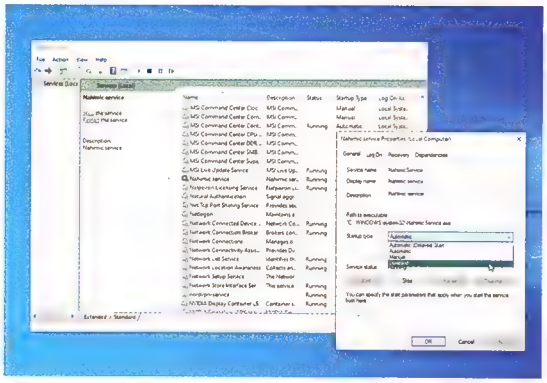
In the February issue of APC, a story on virtual machines mentioned that we can get images for old Windows boot disks at ***www.allbootdisks.com*** *– do these images contain the original Windows version, or do they include all the updates to these older versions that were supplied before MSFT support ended? It wasn't clear in the article.*
PHIL WEST

APC RESPONDS: These boot disk images aren't suitable for installing Windows – they basically provide boot and repair functions only. If you read the article again, you'll see that Neil has directed you to the website to obtain a boot floppy disk image for Windows 95, because the Windows 95 CD-ROM itself wasn't bootable, and requires this to run.

When it comes to updating older machines, you'll find that most updates and patches are available online. In the case of Windows 95, you'll find key patches at **http://bit.ly/MPCWIN**, while Windows XP users can still manually download all updates – including Service Pack 3 – from Microsoft's own catalog (go to **www.catalog.update.microsoft.com** and search for "XP SP3"). If you're creating a Windows XP virtual machine, once it's up and running you can create your own install media with SP3 and all post-SP3 updates slipstreamed into it using nLite (**www.nliteos.com**). This must be run inside your virtual XP machine, and the ISO file generated, then copied to a safe location on your main machine for future use.

Sound driver lag

I recently updated the BIOS in my Asus ROG Maximus XI PC and then updated the Realtek Audio driver from 6.0.1.8557 to 6.0.1.8960. Everything appeared normal, but when I then tried to open a browser window, there was an 8-10 second delay before the window opened. No such problem in other apps. Reverting to the old driver had no effect – I had to run System Restore to revert my PC to before I installed the driver update. I tried again, but after uninstalling the original driver, I can't install any other driver – ld or new – without the lag returning. Can you help me pin down what's causing the lag?
RICHARD KING



Try disabling Nahimic if you have problems after a sound update.

APC RESPONDS: You're not the only one to complain about a 10-second lag affecting all browsers, and at least one person has traced this problem to the Nahimic service, which is installed alongside the Realtek drivers. Nahimic is linked to the sound enhancements used by many motherboards (specifically Asus and MSI) and companion software such as Sonic Studio III, which is installed alongside the drivers.

Start by reinstalling the latest driver, rebooting, and then attempting to disable the Nahimic service – open Task Manager to the Services tab, right-click "NahimicService," and select "Stop." Now open your browsers to see if the problem is eliminated. If it is, then you've identified the cause of your problem. For a more permanent fix, right-click "NahimicService" again, but this time choose "Open services." Right-click its entry in the Services panel and choose "Properties," then click "Startup type" and change it to "Disable." Click "Apply > OK" and reboot your PC – this should eliminate the problem once and for all.

Prioritising driver updates

I would like to know which driver updates are most important, and which ones can slide. I use the free version of Driver Max that only allows me to download two updates a day. After the scan there's always a lot of drivers that are very cryptic. I do the chipset, video, LAN, and sound updates, which leaves things like buses and others that I don't understand. My question is, what is important, and what can be left alone?
JIM PICHE

APC RESPONDS: It's an impossible question to answer, Jim, because while it's advantageous to have the latest versions of some drivers – your graphics being the most notable case in point – with others it depends on whether the driver update fixes a major problem, improves performance, or adds new features. Indeed, in some cases, such as with sound cards, it's often a case of "If it ain't broke, don't fix it!"

That said, your main issue is relying on Driver Max to keep your drivers up to date. Any app that limits you to just two updates per day isn't worth persevering with – either bite the bullet and purchase a lifetime license (US$29.80 at time of writing) or look for another approach. The obvious alternative is Snappy Driver Installer, which is free, portable and open source. Download and run the Lite version from **https://sdi-tool.org/** – it's a little less user-friendly than other driver tools, but it's a good non-restricted alternative.

Most people's needs can be met by the update tool supplied by their PC or motherboard manufacturer, which covers all the core drivers, such as chipset, SATA/RAID and onboard graphics, sound, and

network drivers. Check the support section of your manufacturer's website for details – such as Live Update from MSI and Asus, or HP Support Assistant. Pair it with the official AMD or Nvidia graphics drivers, which automatically alert you to updates, and you'll be covered.

PC switches on and off randomly

I feel my sanity fraying. My HTPC has started powering on (and off) randomly. I've ruled out the PSU with three different tries. I've flashed my BIOS. I'm fairly confident I don't have a short anywhere. Is my Z87M-plus motherboard just going bad?
JAMES BREEN

APC RESPONDS: There are a few more tests to perform. First, check the various cables connecting bits and pieces to your PC. If these appear to be undamaged and securely plugged in – or the problem persists after you've swapped them – then you'll have to bite the bullet and strip your PC down to its bare bones (don't forget to earth yourself first). This involves unplugging everything from the motherboard, including components, cables and – yes – the CPU fan and heatsink, and CPU itself. Next, remove the motherboard from your case. Carefully clean off any dirt or grime you come across using a can of compressed air for loose debris, and a cotton swab and rubbing alcohol (you'll find plenty of advice online) to ensure all connections are clean. Make sure the motherboard is left to dry completely.

Check your case carefully to ensure there are no loose screws that may have been responsible for any shorts, then refit the motherboard carefully before plugging in all removed components and cables, checking each one for possible signs of wear and tear. Finally, power the PC back on to see whether it's made any difference. If the problem remains, then it may be time to look at replacing it.

No 4K encoding?

When attempting to convert (encode) a 3,840 x 2,160 video using Wondershare UniConverter on my Dell XPS 15-inch 9500 'Creator Edition' laptop, Task Manager shows the encode process immediately switch from my Nvidia GeForce GTX 1650 Ti GPU to the integrated Intel UHD GPU. It seems the GTX 1650 Ti is only capable of converting video up to 1,920 x 1,080 with Nvidia GPU acceleration enabled. Anything higher – including 2,704 x 1,520 – defaults to the slower Intel UHD GPU, where encode times are tripled. Wondershare states it's a hardware limitation of the GeForce GTX 1650 Ti, but why? I can find no definitive answer via Dell or Nvidia's online communities.

A defective USB port in the Corsair Commander Pro caused havoc on Jon's PC.

I've tried disabling the Intel UHD graphics driver with Device Manager to try and force priority onto the FTX 1650 Ti. System stability is compromised, and it has no impact on Nvidia GPU acceleration. Why is the GeForce GTX 1650 Ti not capable of converting video resolutions above 1,920 x 1,080? If it's a hardware limitation, why did Dell offer a 4K-limited GPU on a premium system that promotes 4K creativity?
DEREK R

APC RESPONDS: There's no hardware limitation we know of preventing you from using Nvidia's NVENC encoder to rip 4K video with a GeForce 1650 Ti chip – have you tried a different software package? For example, HandBrake (**www.handbrake.fr**) supports NVENC-accelerated encoding, and APC has successfully converted 4K video using its NVENC codec with a GTX 1660 SUPER.

There are, however, good reasons why you might prefer to put up with the slower CPU-based encoder. First, the NVENC encoder is optimised primarily for real-time streaming, which basically means it uses higher bit-rates to produce video of comparable quality to the CPU encoder, which translates to significantly larger file sizes – more than twice the size in your case thanks to the GTX 1650 Ti's older Volta architecture. There may also be visibly inferior image quality. However, if space isn't an issue but encoding times are, then give HandBrake a try using its Production Max or Production Standard presets if you're looking to convert to 4K.

AMD USB Follow-up

Thank you for your response to my query regarding my USB issues on my Asus X570 ROG Crosshair Hero VIII. I wanted to follow up and let you know my findings.

Unfortunately, none of your suggestions worked, and I ended up buying a new motherboard of the same model. Surprisingly, the new motherboard exhibited the same issues, which meant it was not the motherboard.

After much trial and error, it turned out that my Corsair Commander Pro module that controlled the RGB lighting and case/AIO fans on my Corsair was the culprit. The Corsair H115 RGB Platinum AIO is plugged into one of two USB ports in the Pro, which was defective. If I plugged the AIO into the second USB port, the errors vanished.

Secondly, I also purchased Phanteks' RGB NEON light strips, which are supposed to work with Corsair's iCue app. While the app recognised the light strips, it couldn't control the RGB colour effects. To get it to work, I had to disable the Asus plug-in from iCue and install Asus Aura Sync, which controlled the light strips with no issue. I should note that you can't use Asus's Armory Crate as it conflicts with iCue, which loses the AIO cooler in the app. Again, thank you for your support.
JON SHIMAMOTO

APC RESPONDS: Thanks for following up with us, and for sharing your eventual fix, as well as tips for handling various lighting setups. It just goes to show that trial and error is often the only way to truly get a handle on a problem – glad you've finally got it sorted.

Tidy up with virtual desktops

Alex Blake explains how to make one PC be many PCs in one.

Tired of managing an unruly mess of a desktop, with tons of windows clogging up your view? There is a solution: Windows 10's virtual desktop feature. This lets you create a new instance of your current desktop setup, enabling you to divide your tasks into separate desktops, all walled off from each other. You might have a desktop with your work documents and apps open, for example, with another used for unwinding during your lunch break. That way, everything is neatly ordered and in control, without becoming overwhelming. You can't have different wallpapers or themes for your different desktops – instead, think of them as close copies of each other, with the main demarcation being the apps and windows you have open on each.

And instead of littering your desktop with shortcut icons for your favorite apps and games, you can pin them to your Start menu. Rather than using Windows 10's rather plain implementation, we are going to look at a few apps that give you much more control, helping to clean up your desktop and beautify your Start menu at the same time. All the methods outlined here are straightforward and easy to follow. Let's get started.

YOU'LL NEED THIS
Windows 10
You can use Windows' own Task View option, or try a number of third-party apps.

01 CREATE A VIRTUAL DESKTOP

There are several ways to create a new virtual desktop, either through Task View or by using a keyboard shortcut. The first method is to press the "Task View" button immediately to the right of the Windows 10 search box. If you can't see this button, press the Windows button (Win) and Tab. Both methods open the Task View, which displays all your open app windows. At the top of the screen you will see a button reading "+ New Desktop." Click it and a second desktop icon opens at the top of the screen; click that to switch to it.

If you prefer a quicker way, simply press Ctrl-Win-D. This create a new virtual desktop and immediately switches to it.

02 REMOVE UNWANTED DESKTOPS

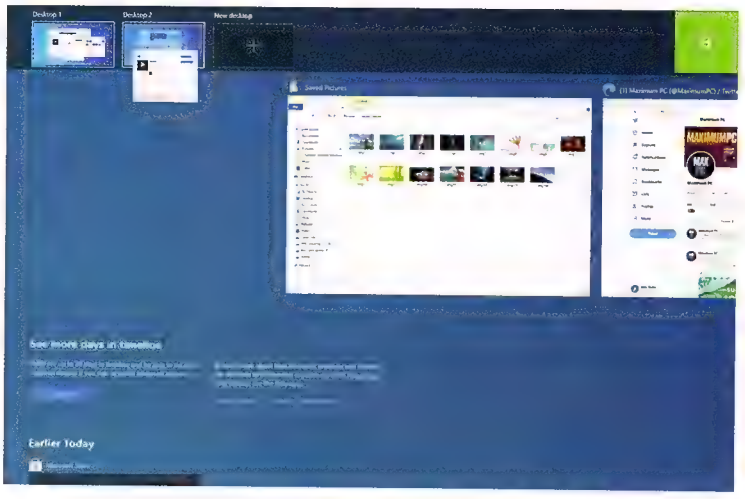
Once you have finished with a virtual desktop, you can delete it to keep things in order. Press the "Task View" button or Win-Tab to open Task View. At the top of the window you will see "Desktop 1," "Desktop 2," and so on. Hover over the desktop you want to delete and an X appears above its top-right corner; click it to remove the virtual desktop. If you prefer to use keyboard shortcuts, however, simply press Ctrl-Win-F4 to delete the currently open virtual desktop. If you have windows open, these are moved to the next available desktop (they move right to left when looking at the Task View window).

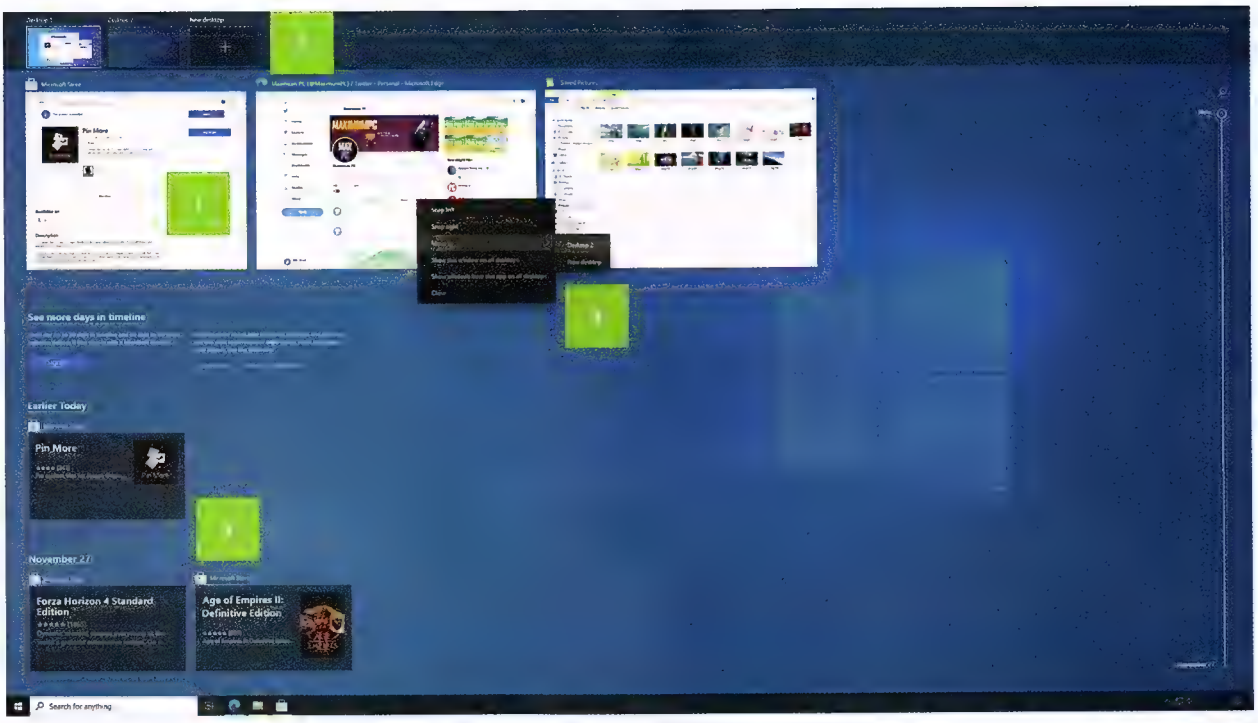
03 NAVIGATE BETWEEN VIRTUAL DESKTOPS

The standard way to navigate between your virtual desktops is to use Task View. When you press Win-Tab, you see previews of your virtual desktops along the top of the screen. Each one shows the windows and apps open on each desktop. If you hover your mouse over one [Image A], the apps that are open on that desktop appear lined up on your screen, and you can use the mouse or arrow keys to move between them. Click an app and you are taken to that desktop with the app you clicked in the foreground.

Keyboard shortcuts make it quick and easy to switch between all your different virtual desktops. Simply press Ctrl-Win-Right or Ctrl-Win-Left to move right and left along the list of virtual desktops you have open. If you are using a trackpad, you can use a four-finger swipe left or right instead to move through your desktops even more quickly.

Note that when you switch to a new desktop, any apps that were running on your original desktop continue operating. That means if you are playing music on Desktop 1 and switch to Desktop 2 without pausing it, you can still hear your music even though your music app is not open on the new desktop.





The Task View

1 Open apps
All apps open on the current desktop are shown here. Hover over a different desktop and you instead see the apps that are open on that desktop.

2 Active desktops
Your current virtual desktops are shown along the top. You can close them or add new ones as you wish.

3 Right-click options
Right-click an app and you can move it to a different desktop, snap it to a side of your screen, close it, and more.

4 Account activity
The Task View can also can be used to view your history and activity. If you are signed in with a Microsoft account on several devices, you can see their activity here, too.

04 CUSTOMISE YOUR DESKTOPS

Now that we have mastered the basics, we can start going a bit deeper. On the Task View screen, right-click an app. You will see several options: "Snap left," "Snap right," "Move to," "Show this window on all desktops," "Show windows from this app on all desktops," and "Close."

The first two open the desktop with the selected app snapped to the left or right side of your display and your other apps shown on the other side, which is useful for multitasking. Hover over "Move to" and a submenu opens out, with options for moving the app to an existing virtual desktop or a new one. Another way to move apps between desktops is to simply drag and drop them [Image B]. You can drag an app from the preview of one desktop to another. If you drag it over the "New desktop" button and release, it creates a new virtual desktop and is moved there.

"Show this window on all desktops," as the name suggests, duplicates the window to appear on all your virtual desktops. However, if you have more than one window open from the same app, it only duplicates the window that you have selected. To copy everything from that app, choose "Show windows from this app on all desktops" instead. Finally, you can close an app window by selecting the last option in the menu.

05 MULTITASKING SETTINGS

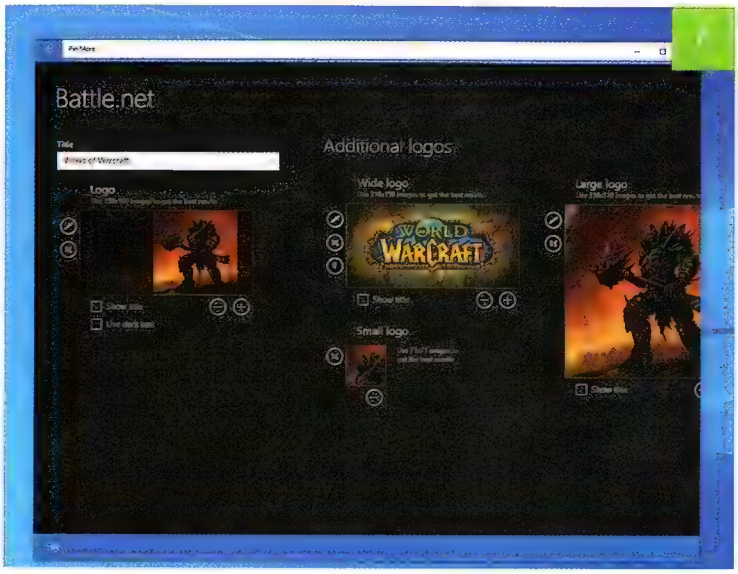
If you want more control over your virtual desktops, open the Settings app and click "System." In the left-hand sidebar, click "Multitasking," then head to the "Virtual desktops" section at the bottom. Here, you can choose whether the taskbar only displays apps that are open on the currently selected virtual desktop, or whether it shows apps that are open across all your desktops. You can also change whether the app switcher shortcut (Alt-Tab) shows apps from every desktop or just the one you are currently using.

If you switch to an app that is open in another desktop – whether that is by clicking its taskbar icon or using the app switcher – you are immediately taken to the desktop that it is open on. However, if you have an app open on another desktop, Shift-clicking the app's icon in the taskbar doesn't open another instance of it on your current desktop. You can open the app from the Start menu or by searching for it, but it seems you can't open it across multiple desktops using the taskbar.

06 GET PIN MORE

There are other ways to tidy up your desktop. One way is to pin your frequent apps and folders to the Start menu instead of covering your desktop in a sea of shortcut icons. To do so, we are going to use Pin More, an app that enables you to pin all sorts of things to your Start menu, including documents, folders, websites, and games from Steam, Origin, Battle.net, and Ubisoft Connect.

Open the Microsoft Store app and search for "Pin More." It costs $4.45. There are free alternatives, but



none that cover as many bases as Pin More. Once you have downloaded and installed it, open the app, then choose what you want to pin.

07 PIN A FOLDER

From the Pin More main menu, click "Folders." Enter a title, click "Pick folder," navigate to the folder you want to use, then click "Select Folder." Click "+" under "Logo" to add an image to use as an icon for the folder; this is the icon that will show up on the Start menu tile. You can move the outlined square to include just the portion of the image you want. If the image is stretched or squashed, use the crop button to resize it. The "Logo" option is required, but you can add small, wide, and large logos, too, which will be used if you change the tile's size on the Start menu.

Once you have chosen an image, you can make a few adjustments should you wish. "Show title" and "Use dark text" are deselected by default. The first displays the folder title over the bottom-left corner of the icon, while the second switches the text's colour from white to black. To the left of the icon are buttons to crop it and select a color from the image; any colour you pick is used as the background for the other tile sizes [Image C]. Finally, you can copy the image chosen for the wide tile for use on the required logo tile by clicking the third button to the left of the wide tile (it looks like a square with an arrow underneath it).

When you are done, click "Pin to Start" in the bottom-left corner. This adds the tile to the Start menu, where it can be moved and resized as needed.

08 PIN A GAME

While the process for pinning websites and documents is like that for folders, pinning games is a little different. If you have Origin, Battle.net, or Ubisoft Connect installed, Pin More automatically detects the games in your account and lists them in a grid of tiles. The same is true for Steam, except you must enter either your Steam ID or your profile name first, and ensure your profile is set to public.

To pin a game, first select it from the grid. You will see a menu similar to that for pinning a folder, except the logo and wide logo fields are already populated with the game's artwork (the small and large logos are filled with a colour automatically drawn from the artwork).

If you feel the artwork doesn't match your taste or doesn't look right (as is often the case with the square logo), click the minus button underneath it, and add a new image, following the same process as we did when pinning a folder. When you are finished, click the "Pin to Start" button and rearrange it if required.

09 WHY USE TILEICONIFIER?

Pin More is very easy to use but is a little limited. For example, there is no option for pinning apps, so you have to stick with the default Windows 10 style, which may not be ideal (especially if you want to change the icon or remove the app's name from the tile).

In these cases, we recommend using TileIconifier, a free app that enables you to pin almost anything and customise its appearance [Image D]. To get started, download it from **http://bitly.com/TileIconifier** (the URL is case-sensitive).

10 CHOOSE A NEW ICON

The first thing you will notice is that TileIconifier is a little more old-fashioned than Pin More. That's OK, it's still a piece of cake to use. After it has finished loading, a list of your installed apps appears on the left – scroll down until you find the one you want, or search for it in the "Filter" box. Click an app to select it. Double-click either the "Medium Icon" or "Small Icon" box. A window opens showing every icon stored within the app's .exe file. You can choose one here or select one from elsewhere by clicking "Use custom image" and browsing to a file. You can use any image or icon file.

11 TWEAK ITS APPEARANCE

Once you've chosen an icon, there are several changes you can make. Directly under the icon is a slider that adjusts the zoom level for the image. You can also use the controls to the right, which include a button to align the image to an edge or the center of the frame. There is a checkbox to ensure changes applied to one icon size also apply to the other.

Third-party alternatives

As we touched on in the introduction, multiple desktops are not totally separate from each other, with your original instead working as a kind of template for subsequent additions. That means that if you set a new wallpaper on a new desktop, it is also applied to the original. Any icons you move on your desktop, or settings you change, are rolled out across all active desktops. You can't rename your desktops, either.

If you want more control than Windows 10 offers you, there are third-party alternatives that are worth a try. Peach (**http://peachapp.net**), for example, enables you to rename desktops, or pin apps on top of other apps on every desktop, and adds a bunch of new keyboard shortcuts for managing virtual desktops.

Dexpot (**http://dexpot.de**) gives you much more control over the visual aspect of running multiple desktops, letting you give each one a different wallpaper and move icons wherever you like without other desktops being affected. It also has a ton of extra options, including customisation rules, configurable hotkeys and mouse gestures, and more.

Below this is a drop-down menu for the background colour. You can choose from several presets or use a custom colour picker. This only has an effect if you use an image with transparent areas or if you zoom your icon out far enough that the background color shows. Finally, you can hide the app's name or change its color from light to dark.

12 PIN A FOLDER

Pinning a folder requires a slightly different process. Click "Utilities" in the top menu, then click "Custom Shortcut Manager." Click "Create New Shortcut" in the new window. You can select one of Windows 10's special folders (such as the Action Center or the Recycle Bin), or use a custom folder of your choice. If you select the latter option, click "Browse" to find the folder you want.

Click the icon in the bottom-left to change the shortcut's image and enter its display name in the "Shortcut" box. Choose whether you want the new shortcut to appear for every user on your PC or just you, then click "Generate Shortcut." After you have made your changes, click "Tile Iconify!" and let the app get to work.

13 PIN THE NEW SHORTCUT

Unlike Pin More, TileIconifier does not automatically pin the finished product. Instead, it is added to the TileIconify folder in your Start menu. Find the new shortcut there, right-click it, then click "Pin to Start," and reposition or resize it to your taste.

TileIconifier's advanced controls

TileIconifier has several useful features if you want to go deeper with your tile customisation. One of the most useful is the batch tool. Click "Utilities" in the TileIconifier menu bar, then click "Batch Shortcut Operations." Put a check in the checkbox next to every shortcut you wish to amend, then choose what changes you want to apply. It is particularly useful if you want to theme your Start menu by adding a uniform background colour to all your tiles, for instance, or if you want to add or remove the app name on each shortcut.

Elsewhere, you can find all your custom shortcuts by clicking "Utilities," then "Custom Shortcut Manager." From here, you can create a new shortcut, delete existing ones, and adjust the settings for previously created shortcuts. You can also see whether the shortcut affects just you or all users on your PC, and what type it is (Explorer folder, Microsoft Store app, and so on).

Some apps may refuse to be tiled properly. If that happens, select your desired app from the list, then click "Quick Build Custom Shortcut." This creates a second shortcut using the same parameters as the original, which you may be able to pin properly instead.

MAC

Master Messages in Big Sur

The new version of macOS features some big improvements in Messages.

IT WILL TAKE
30 minutes
YOU WILL LEARN
How to use the new features in Big Sur Messages
YOU'LL NEED
macOS 11

The Messages app in Big Sur is a major improvement on the version in Catalina. It's now on a par with most of its rival messaging apps and has features that bring it much more into line with Messages on the iPhone and iPad.

Among those new features are the ability to pin up to nine messages to the top of the messages list and the option to reply directly to a message in a group conversation, creating a separate thread.

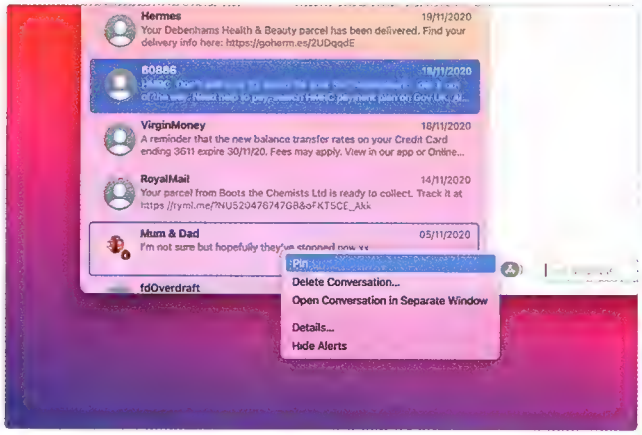
You can now also create a custom image for group conversations and 'mention' others by typing their name. Messages now allows you to configure notifications so you only get an alert when someone mentions you.

If you love sharing GIFs (animated messages), you can now search for them within Messages and easily add them to a conversation, and you can add a bit of personal expression with a Memoji, too. Searching messages has also been improved and is now faster.

GENIUS TIP!
You can change the text size of messages, as well as choose whether effects and sound effects are played in Preferences.

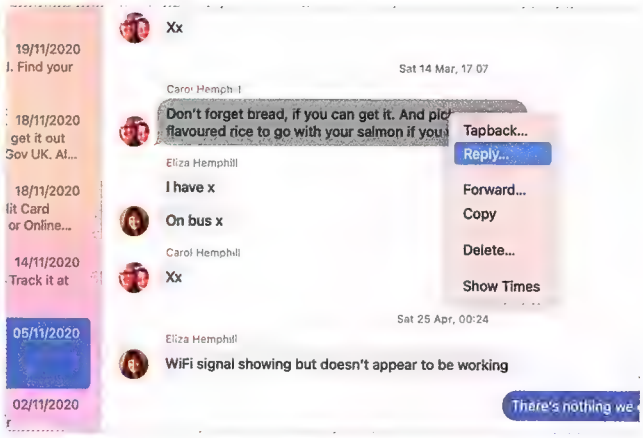
JARGON BUSTER
When you control-click on a message and choose **TAPBACK**, you can give a thumbs up, heart, or other emoji-style response.

HOW TO Do more with Messages


Hermes
Your Debenhams Health & Beauty parcel has been delivered. Find your delivery info here: https://goherm.es/2UDqadE
19/11/2020
60886
18/11/2020
VirginMoney
A reminder that the new balance transfer rates on your Credit Card ending 3611 expire 30/11/20. Fees may apply. View in our app or Online...
18/11/2020
RoyalMail
Your parcel from Boots the Chemists Ltd is ready to collect. Track it at https://tyml.me/?NUS20476747G8&oFKT5CE_Akk
14/11/2020
Mum & Dad
I'm not sure but hopefully they've stopped now xx
05/11/2020
fdOverdraft
Pin
Delete Conversation...
Open Conversation in Separate Window
Details...
Hide Alerts

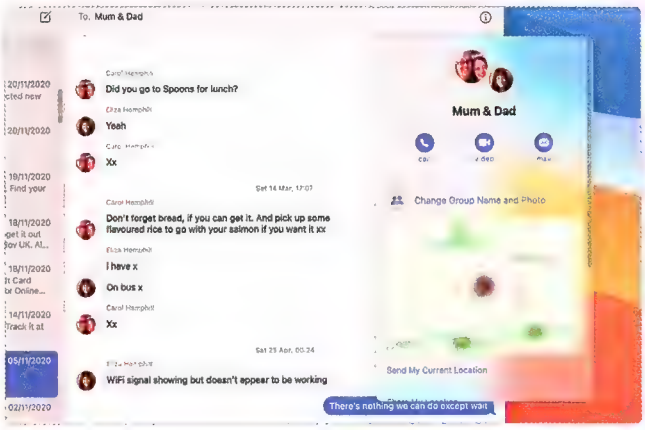
01 PIN A CONVERSATION

Pinning a conversation displays that particular conversation at the top of the list of messages. Navigate to the conversation you want to pin in the list,control-click on it and choose Pin. You can unpin it in the same way.



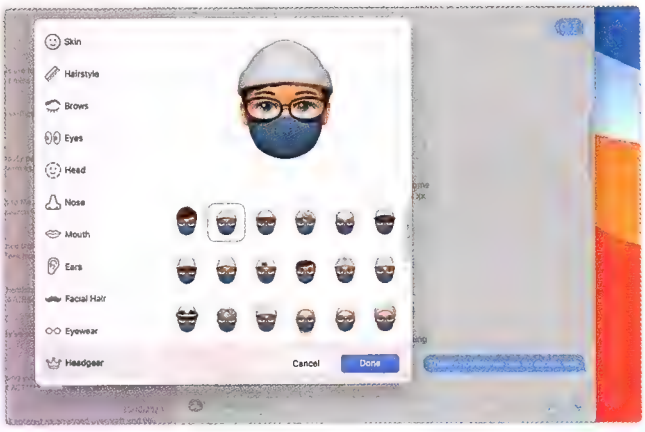
02 REPLY INLINE

Control-click on the conversation you want to reply to and choose 'Reply...'. Your reply can be seen beneath the message, rather than as a new one. You can also Tapback a message with a quick reaction by control-clicking on it.


To: Mum & Dad
Did you go to Spoons for lunch?
Yeah
Xx
Don't forget bread, if you can get it. And pick up some flavoured rice to go with your salmon if you want it xx
I have x
On bus x
Xx
WiFi signal showing but doesn't appear to be working
There's nothing we can do except wait
Mum & Dad
Change Group Name and Photo
Send My Current Location

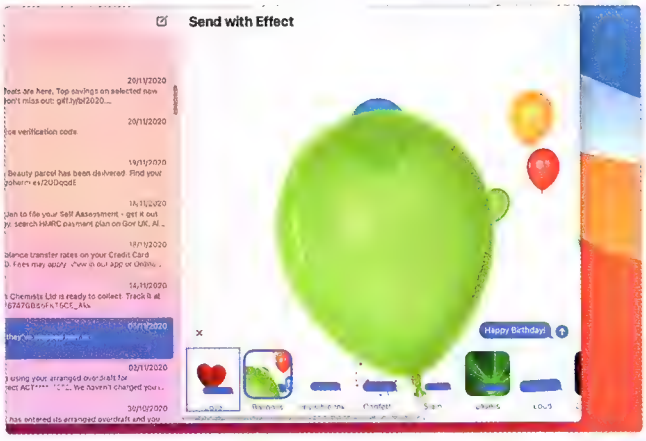
03 SET A GROUP PHOTO

Locate the group in the messages list and select it. Click on the 'i' at the top right of the main window and choose 'Change group name and photo'. Click the photo icon, scroll through the images from your Library and choose one.



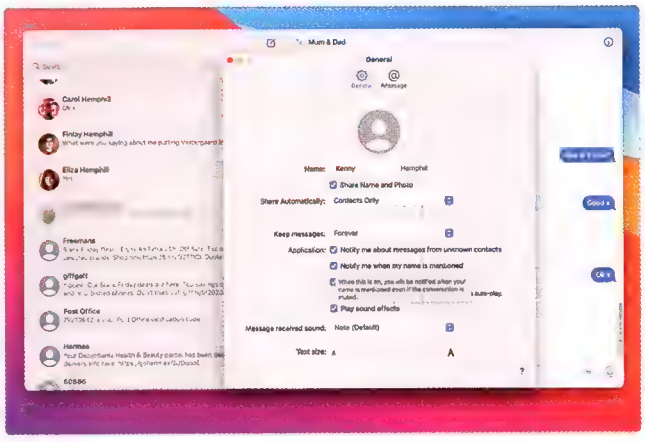
04 CREATE A MEMOJI

In any message, click the 'A' next to the text box. Choose Memoji Stickers. Click on the three dots '...' (top left) and select New Memoji. Now, go through the options and create your Memoji. Click Done when you're finished.



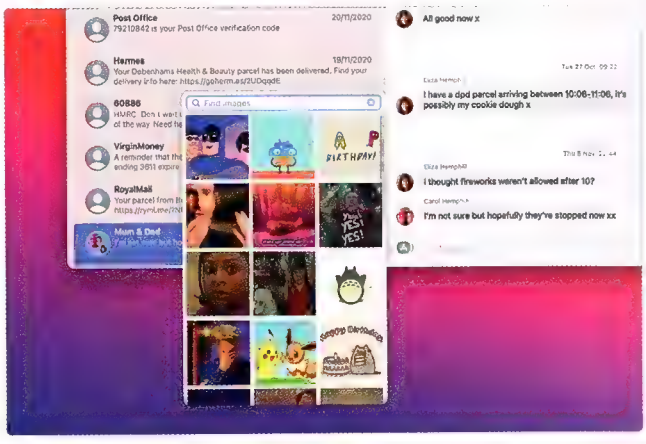
05 ADD EFFECTS TO A MESSAGE

Type your message in the text box. Before pressing Send, click the 'A' and choose Message Effects. Select the effect you want, here we've gone for floating balloons, and press return to send the message with the effect.


Mum & Dad
General
Share Name and Photo
Notify me about messages from unknown contacts
Notify me when my name is mentioned
Play sound effects

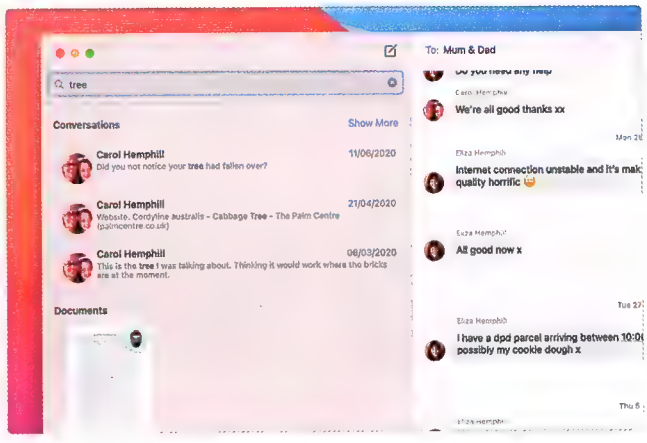
06 MENTION NOTIFICATIONS

Click on the Messages menu and choose Preferences > General. Check the box 'Notify me when my name is mentioned'. Navigate to the group message, then control-click on it and choose Hide Alerts.


Post Office
79210842 is your Post Office verification code
Hermes
60886
VirginMoney
RoyalMail
Mum & Dad
All good now x
I have a dpd parcel arriving between 10:06-11:06, it's possibly my cookie dough x
I thought fireworks weren't allowed after 10?
I'm not sure but hopefully they've stopped now xx

07 ADD A GIF

In the message window, click the 'A' next to the text box. Choose '#images'. Scroll through the list of GIFs to find one or start typing in the search bar to filter them according to your search criteria.



08 SEARCH MESSAGES

In the messages list, start typing in the search bar. Click Show More to see more results. To browse photos or documents without search, click Show More next to Photos or Documents without typing a search query.

iOS

Create custom widgets

Widgetsmith gives control over your Home screen in iOS 14.

When Apple launched iOS 14, it heralded a new era for the iPhone. One of the biggest new features was the introduction of widgets, which can display snippets of information from the app of your choice on your Home screen.

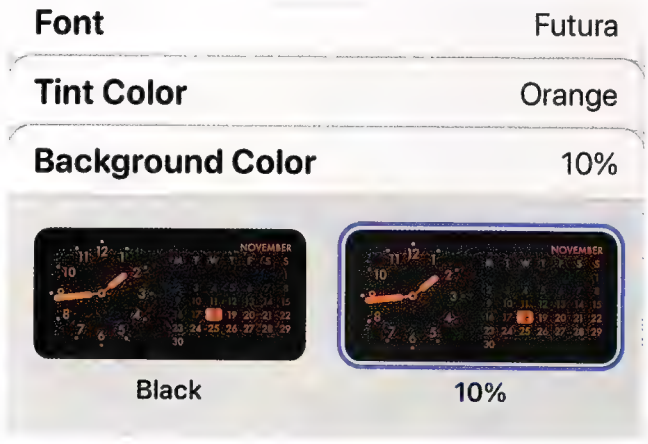
Although Apple has opened the widget system to third-party developers, there's not as much control as you might like. Apple's apps allow for little visual customisation – if you do not like how they look, you are stuck. Widgetsmith does an excellent job at solving that. It has a wide range of widgets that can be tuned to your liking. What's more, the app opens the way to Home screen customisation that simply was not possible before, letting you create a theme that matches your taste. The basic version of the app is free and includes most of what you need, although there is a paid-for version (from $3.49 monthly) that includes widgets for weather and tides. We will not need that today, though.

IT WILL TAKE
5 minutes

YOU WILL LEARN
How to create custom widgets in iOS 14 using Widgetsmith

YOU'LL NEED
iOS 14 or later

HOW TO Create and edit Smart Stacks



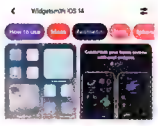
01 GET STARTED

In Widgetsmith, choose your widget size. Here, we will choose Medium. Tap Default Widget, then decide what you want your widget to do. We have selected Clock, giving us a calendar and clock together in one widget.

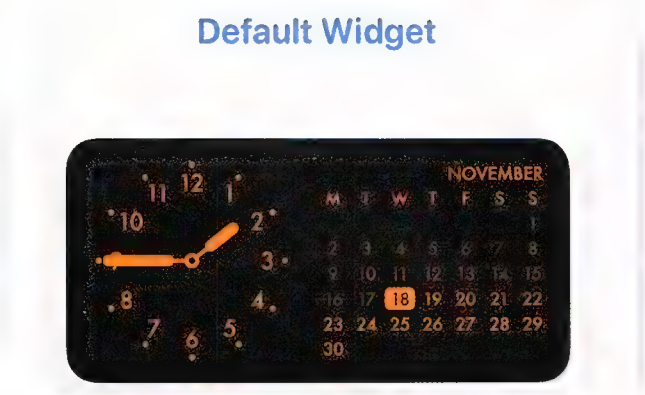
02 CUSTOMISE THE DETAILS

Each widget can be tweaked. For instance, the clock widget lets you change its overall style, theme, location, clock style, and min/sec hand type. Under Aesthetic/Theme, tap Customize Theme for more options.

GENIUS TIP!
With a bit of planning, you can combine Widgetsmith widgets with a wallpaper to create a whole new visual theme for your device.



JARGON BUSTER
When you tap and hold a blank section of the Home screen, you enter jiggle mode. Your apps start to shake, and you can delete or rearrange them as desired.

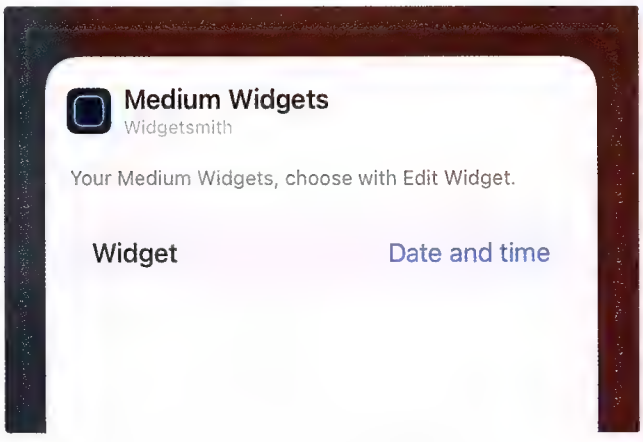


03 CHOOSE A NAME AND SAVE

When done with visual adjustments, tap the name of your widget in the top-left corner. Tap its name in the top-centre to rename it, then tap Save. The widget is now added to Widgetsmith's library on your device.

04 PLACE YOUR WIDGET

Tap and hold a blank area of your Home screen to enter jiggle mode, then tap the '+' button to add a widget. Select Widgetsmith in the list and choose the size of widget you just created, then tap Add Widget.



05 CHOOSE THE RIGHT ONE

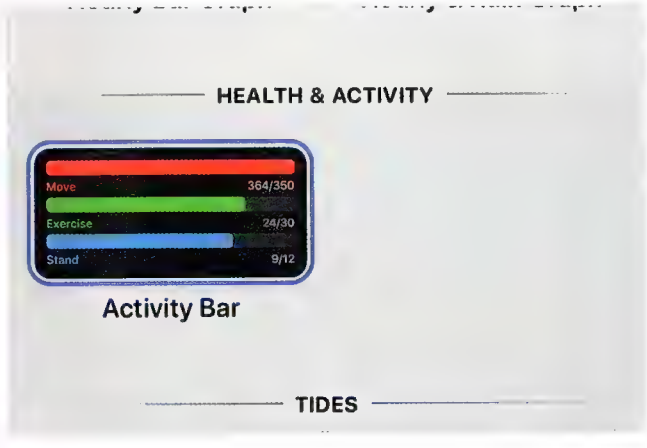
If you have created more than one widget, tap the one you just placed when in jiggle mode so it flips over. Tap the name of the widget, then tap the one you want from the list. Tap the Home screen, then tap Done.

06 CREATE A TIMED WIDGET

Timed widgets change depending on the time of day by setting a time when a standard widget will change its function or appearance. For a timed widget to work, you need a standard widget on your Home screen first.

07 PICK AN ACTIVE TIME

Choose an existing widget in Widgetsmith, then tap Add a Timed Widget. Use the clock hands to choose when it will be active (at other times the standard widget is active). You can add another time slot by tapping the '+'.



08 SET ITS FUNCTION

Tap the widget preview on the edge of the clock (not the one in the centre) to set how it will function and look during the timed period. You can choose a different type of widget if you like. When you are done, tap Save.

Manipulate and work with PDF files

Shashank Sharma breaks down the different things you can do with PDF files, apart from reading and creating them from the blackness of a terminal.

According to the statistics released by Adobe as part of the 25th anniversary of PDF in 2018, more than 200 billion PDF files were accessed using Adobe products in 2017. In the years since, and taking into account non-Adobe products, the sheer number of PDF files accessed in a year, or even on a daily basis is practically incalculable.

The trusted and popular document format started its journey as a proprietary format at Adobe in 1993, and was released as an open standard in 2008. Today, there are a large number of graphical and command-line utilities that you can use to not only read, but also manipulate PDF files.

Here, we'll discuss everything from splitting large PDF files into smaller ones, or merging multiple small files into a single PDF file. We'll also discuss how to churn multiple image files into a PDF document and shrink the size of a PDF file. We'll reveal how to run OCR on your PDF files, edit metadata of PDF files, extract text, or images out of PDF files and more!

Creating a PDF from image files

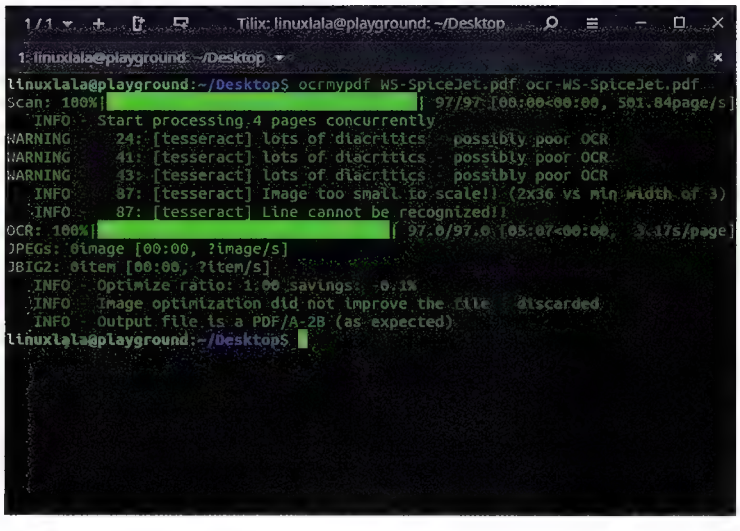
It's a common practice to use your cellphone camera to digitise documents. Unless you're using dedicated scanner apps, you'll end up with image files. You can convert these image files into PDFs using the popular ImageMagick suite.

ImageMagick is a suite of command-line applications and utilities you can use to perform various operations on image files. Whether it's creating GIF images, collage, or otherwise editing your images, all operations can be performed using one of the included utilities. The most popular of these is convert, which can be used to edit, crop, resize, flip, blur and perform myriad other operations on image files.

However, the convert can also be used to stitch multiple image files into a PDF:

```
$ convert image1.png image2.png image3.png output.pdf
```

The simple command expects a series of image files and the output file format as arguments. While this works well if all your image files are the same size – have the same resolution and DPI – if your images are taken from various sources, such as screenshots of your desktop, taken using your camera phone or a DSLR, say, then you'll end up with a PDF file where each page is of a different size. You can overcome this problem by specifying the page size, and other parameters with the `convert` command:


Tilix: linuxlala@playground: ~/Desktop
1: linuxlala@playground: ~/Desktop
linuxlala@playground:~/Desktop$ ocrmypdf WS-SpiceJet.pdf ocr-WS-SpiceJet.pdf
Scan: 100%| | 97/97 [00:00<00:00, 501.84page/s]
INFO - Start processing 4 pages concurrently
WARNING 24: [tesseract] lots of diacritics - possibly poor OCR
WARNING 41: [tesseract] lots of diacritics - possibly poor OCR
WARNING 43: [tesseract] lots of diacritics - possibly poor OCR
INFO 87: [tesseract] Image too small to scale!! (2x36 vs min width of 3)
INFO 87: [tesseract] Line cannot be recognized!!
OCR: 100%| | 97.0/97.0 [05:07<00:00, 3.17s/page]
JPEGs: 0image [00:00, ?image/s]
JBIG2: 0item [00:00, ?item/s]
INFO - Optimize ratio: 1.00 savings: 0.1%
INFO - Image optimization did not improve the file - discarded
INFO - Output file is a PDF/A-2B (as expected)
linuxlala@playground:~/Desktop$

If ocrmypdf reports any warnings about too many diacritics, it doesn't mean that the command has failed.

QUICK TIP

You can only use uppercase letters to define 'handles' in pdftk. You can, however, use a single letter or use them in combination to define 'handles'. For instance, you can use A, B, D, Z, TT or ASD as your 'handles'.

```
$ convert image1.png image2.png image3.png -page A4 output.pdf
```

You can similarly use the `-quality` and `-resize` command options with the `convert` command to affect the final PDF file. The exact command will depend on your input files. However, using ImageMagick for this purpose can take some time if you have a large number of input files, and results in large PDF files.

If you want to keep the size of the final PDF small then you can use img2pdf. It's not available by default in most distributions, but is available in the software repositories. Once installed, you can stitch multiple image files into a single PDF and also specify the page size of the resultant file with the following command:

```
$ img2pdf a.png b.png c.jpg --pagesize A4 -o filename.pdf
```

The `--pagesize` command option expects a case-insensitive value, and in addition to manually specifying the length and breadth of the page, also supports various sizes such as A4, Legal, Letter, A3 and A5.

You can also do other cool things such as turn the page from the default portrait to landscape, by using the `^T` option along with `-pagesize` :

```
$ img2pdf a.png b.png c.jpg --pagesize legal^T -o landscapists
```

Here, we've use the `--pagesize` option to create a legal-sized PDF file, but we've also added `^T` at the end. This informs img2pdf to create a landscape output file.

Refer to the main page for img2pdf for details about the different command options.

Reducing PDF files

Most email services, such as Gmail, Yahoo and others restrict the size of attachments. What happens if you need to share a large PDF file with your peers? One option is to upload the content to services such as Google Drive or DropBox, but you can alternatively reduce the size of the PDF file with simple command-line tools.

Our tool of choice for this is Ghostscript. It's an interpreter for the Postscript language and PDF files, and if it isn't already available on your distro, you can install it using software repositories. The command `sudo apt install ghostscript` will install the tool on Debian, Ubuntu and other DEB-based distros. If you're running a RPM-based distro such as Fedora, you'll need to run `sudo dnf install ghostscript`.

The actual Ghostscript command to reduce the size of PDF files involves quite a few command options. Let's look at the command first and we'll then discuss the different command options:

```
$ gs -dNOPAUSE -dBATCH
-sDEVICE=pdfwrite\
→ -dCompatibilityLevel=1.4
-dPDFSETTINGS=/ebook\
→ -sOutputFile=small.pdf
original-file.pdf
```

Since the complete command is quite long, we've had to split it across multiple lines using the \ symbol.

The most important command option, and the one that actually shrinks the size of PDF files is the `-dPDFSETTINGS` option. The rest can be used as it is. The `-sDEVICE` option can be used to alter the output file format. The ghostscipt command supports a large variety of output formats, including PDF, jpeg, PS, and more. Run the `gs -h` command for a list of all supported devices. For our purposes, since we wish to create a PDF file, we've opted for pdfwrite as the `-sDEVICE` .

OPTION	PURPOSE
-DNOPAUSE	DISABLES THE PROMPT AND PAUSE AT THE END OF EACH PAGE
-DBATCH	EXIT GHOSTSCIPT AFTER PROCESSING THE LAST FILE
-SDEVICE	SPECIFY THE OUTPUT DEVICE.
-DCOMPATIBILITYLEVEL=1.4	SPECIFY THE PDF FORMAT
-DPDFSETTINGS	YOU HAVE THE CHOICE OF SCREEN, EBOOK, PREPRESS

Depending on the size of the original file, and the amount of compression you wish to perform, you'll have to choose either screen or ebook for the `-dPDFSETTINGS` option if you want to reduce the size of the original PDF file. Try both and notice the different in file size, and also the quality of the output file:

QUICK TIP
The man pages, help command and the website for projects like Ghostscript and pdftk are all excellent resources to help you master their myriad capabilities. You'll find various tutorials and instructions online, and even on YouTube that describe how to perform the different operations.

Working with poppler-utils

While we've discussed a number of different utilities to manipulate PDF files in different ways, your Linux distribution has still more tools to offer, for still more operations.

The poppler-utils package is a collection of tools built on Poppler's library API. Each of these tools is designed to work with PDF files and even extract content from them. You can install the poppler-utils package by running the `sudo apt install poppler-utils` command if you're on a Debian, Ubuntu or derivative distribution. Run the `sudo dnf install poppler-utils` command if you're on a RPM-based distro such as Fedora.

The package includes many different utilities such as pdftohtml that can be used to convert a PDF file into HTML while retaining the formatting of the original PDF file. The command `pdftohtml filename.pdf output.html` will first break the pages of the specified PDF file into individual JPEG images and then create an index file called output_ind.html as well as output.html.

You can similarly use the pdfseparate utility to split a PDF file into smaller sections. It works much like the pdftk which we've already discussed, and also supports the use of page ranges. Refer to its man page for more details. The pdfunite utility provides the opposite functionality, and can be used to stitch multiple PDFs together into a single file.

The bottom of the man page for these commands lists the various other utilities that are part of the poppler-utils package such as pdfimages, pdfinfo and pdffonts.

"There are the more advanced operations such as changing the rotation of any page in the PDF file, or encrypting the PDF file with a password."

You can also achieve the same effect using the ps2pdf utility. Again, you'll have to install it from the software repositories on your distribution. Once installed, you can straight away run the `ps2pdf input-file.pdf output-file.pdf` command to produce a smaller file. The utility works by first converting the PDF file into a PS file, and then recreating a PDF file, thereby resulting in smaller size. However, you can also use the `-dPDFSETTINGS=/ebook` or `-dPDFSETTING=/screen` option with the `ps2pdf` command.

OPTION	PURPOSE
-DPDFSETTINGS=/SCREEN	(SCREEN-VIEW QUALITY - 72 DPI IMAGES)
-DPDFSETTINGS=/EBOOK	(LOW-QUALITY - 150 DPI IMAGES)
-DPDFSETTINGS=/PRINTER	(HIGH-QUALITY - 300 DPI IMAGES)
-DPDFSETTINGS=/PREPRESS	(HIGH-QUALITY AND COLOUR PRESERVING - 300 DPI IMAGES)
-DPDFSETTINGS	YOU HAVE THE CHOICE OF SCREEN, EBOOK, PREPRESS

Merge and split

Along with g hostscipt, pdftk is one of the most versatile PDF utilities. According to its man page, if a PDF is electronic paper, then pdftk is an electronic staple-remover, hole-punch, binder, secret-decoder-ring and X-ray glasses. You can use the tool to merge or collate different PDF files into a single document, split large PDF files into smaller ones, or even burst a PDF file such that every page becomes an individual PDF file. Then there are the more advanced operations such as changing the rotation of any page in the PDF file, or encrypting the PDF file with a password.

As with the other utilities that we've discussed in this tutorial, you'll have to use the software management tool on your distribution to install pdftk from the software repositories.

To perform a merge operation, where you join several small PDF files into a single document, the tool expects a space-separated list of PDF files in the order you want them and the name of the output file:

```
$ pdftk 1.pdf another.pdf 3.pdf
fourth.pdf output combined.pdf
```

Combine PDFs

You can use pdftk to string together as many PDF files as you like. Make sure you specify files in the order you want them in the output file. If all your files are sequentially numbered or named, and in the same directory, you can also use wildcards with pdftk instead of typing the name of each file individually:

```
$ pdftk *.pdf output compilation.
pdf
```

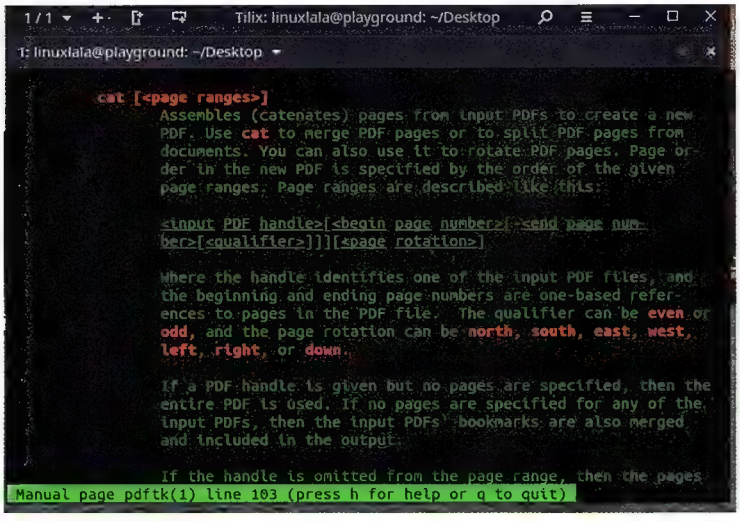
While these examples add all the pages of the input files to the output, you may on occasion only want to use specific pages from different PDF files. You can even do that with pdftk using its 'handles' feature:

```
$ pdftk A=first-file.pdf B=second-
file.pdf cat A1-3 B2-5 output
mixed.pdf
```

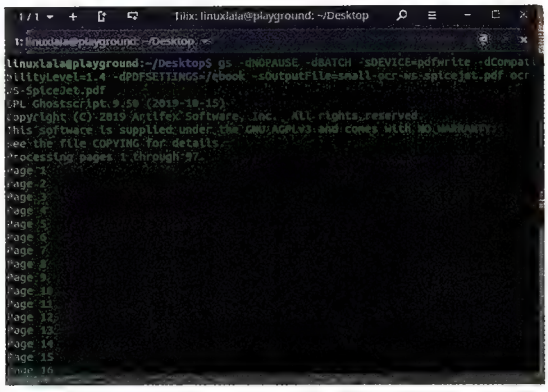
Notice how we've used the letters A and B for different files. These are called 'handles'. You can use multiple such 'handles' with pdftk where each 'handle' is a separate PDF file. You'll also notice that unlike the original examples, we've also added cat to this command. This enables us to refer to the different 'handles', otherwise pdftk is unable to locate the different PDF files.

Finally, we've used page ranges with the different 'handles' to define the sequence of pages in the final output file. There are many different options available to you when working with page ranges. Apart from using numbers, such as 1-4 or 20-32, you can also use certain words such as end, odd or even. A page range of 14-end means all pages from 14 to the end of the file. Similarly, the page range 14-20odd will only include odd numbered pages within the given range. The following examples will help you better appreciate the page range feature of pdftk:

```
$ pdftk A=first-file.pdf B=second-
file.pdf cat A1-3 B2-end output
combined.pdf
$ pdftk A=first-file.pdf B=second-
file.pdf cat A1 B1-3 A2 output
mixed.pdf
$ pdftk A=first-file.pdf B=second-
file.pdf cat Aodd B1-20even output
mixed-even-odd.pdf
```


Tilix: linuxlala@playground: ~/Desktop
1: linuxlala@playground: ~/Desktop
cat [<page ranges>]
Assembles (catenates) pages from input PDFs to create a new PDF. Use cat to merge PDF pages or to split PDF pages from documents. You can also use it to rotate PDF pages. Page order in the new PDF is specified by the order of the given page ranges. Page ranges are described like this:
<input PDF handle>[<begin page number>[-<end page number>[<qualifier>]]][<page rotation>]
Where the handle identifies one of the input PDF files, and the beginning and ending page numbers are one-based references to pages in the PDF file. The qualifier can be even or odd, and the page rotation can be north, south, east, west, left, right, or down.
If a PDF handle is given but no pages are specified, then the entire PDF is used. If no pages are specified for any of the input PDFs, then the input PDFs' bookmarks are also merged and included in the output.
If the handle is omitted from the page range, then the pages
Manual page pdftk(1) line 103 (press h for help or q to quit)

The pdftk tool can also be used to rotate pages in a PDF file. The man page describes how to use keywords such as left, right, east and south to describe the rotation.



The -dPDFSETTINGS=/ebook option can result in reduced PDF sizes. This 39MB file dropped down to 18MB with this command.

In the third example, we've asked pdftk to take all the odd-numbered pages from the first file, and all even-numbered pages from the first 20 pages in the second file. When working with 'handles', you can't use pdftk with regular PDF files.

```
pdftk A=file1.pdf B=file2.pdf cat
Aodd Beven another-file.pdf
output error.pdf
Error: Unexpected text in page
range end, here:
  another-file.pdf
  Exiting.
  Acceptable keywords, for
example: "even" or "odd".
  To rotate pages, use: "north"
"south" "east"
    "west" "left" "right" or "down"
Errors encountered.  No output
created.
Done.  Input errors, so no output
created.
```

In the example above, no errors would be reported if instead of referencing another-file.pdf directly, another handle was used in its place:

```
pdftk A=file1.pdf B=file2.pdf
```

Remove text watermarks from files

As useful as mobile scanning applications such as CamScanner are, the free versions of such programs often insert watermarks to the finished file. If you're annoyed with watermarks such as "Scanned with CamScanner" or other such watermarks, there's an easy fix to remove them.

You'll need the ocrmypdf, pdftk and the pdftops tools. The latter utility is available as part of the popper-utils package on Linux distributions.

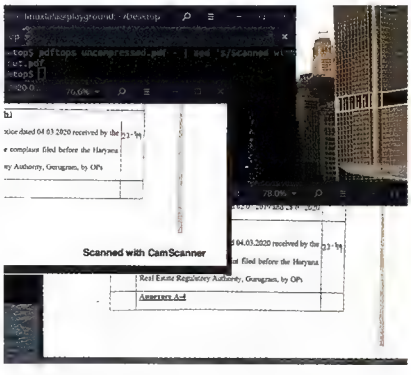
The first step is to OCR the PDF file with the `ocrmypdf file.pdf ocr-file.pdf` command. Next, we need to uncompress the PDF file so as to be able to edit it in text editors. This is done using the pdftk utility:

```
$ pdftk ocr-file.pdf output
uncompressed.pdf uncompress
```

We're finally ready to remove annoying watermarks. This process involves using the pdftops as well as the ps2pdf utilities:

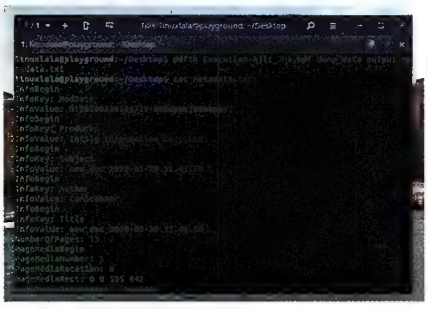
```
$ pdftops uncompressed.pdf - | sed 's/
Scanned with CamScanner//' | ps2pdf
- nowatermark.pdf
```

The nowatermark.pdf file no longer contains the annoying text string. For this technique to work, the PDF must have a text watermark.



Depending on the watermark technique used, this doesn't work on all PDF files.

Change the metadata of PDF files



01 PRINT THE CURRENT METADATA

We'll be using the pdftk utility to alter the metadata of PDF files. Run the **pdftk file.pdf dump_data output metadata.txt** command. This will create a data dump in the metadata.txt file for the specified PDF file.

02 EDIT THE METADATA

The **data_dump** command option of pdftk reads a single input file and reports its metadata including bookmarks, and page metrics such as media, page rotation, in addition to the title, author and so on. You can edit this file in any text editor of your choice.

03 UPDATE THE PDF FILE

The information in the generated metadata.txt file contains key value pairs such as 'InfoKey: Title' followed by 'InfoValue: This is the title'. After you've made the changes, update the PDF file with new metadata by running the **pdftk file.pdf update_info metadata.txt output updated-metadata-file.pdf** command.

C=another-file.pdf cat Aodd Beven C output works-now.pdf

When working with page ranges, it's also important to remember that for `pdftk` , a page range of `1-6` isn't the same as `6-1`. While the former means the first six pages in sequence, the latter means that pages are assembled in reverse order, starting from the sixth.

Put another way, a page range of `1-5odd` results in pages 1, 3 and 5, in that order. However, a page range of `5-1odd` would result in pages 5, 3, and 1 in that order.

For particularly large PDF files, you can also use the `r` keyword to refer to pages in reverse order. That is, `r1` means the last page, `r2` means the second last page and a range of `r1-r3` means the last three pages, starting from the end.

Splitting PDF files is just as easy with pdftk because all you have to do is define the page range:

```
$ pdftk filename.pdf cat 1-5 output fivepages.pdf
$ pdftk filename.pdf cat 1-5 10-end removepages6-9.pdf
```

As you can see, you can also use the page range to either split a PDF into smaller parts, or remove entire pages. Unfortunately, there isn't a single command that can help you split a 100-page PDF file into five smaller ones each with 20 pages. However, if you want to break a PDF file such that each page becomes a separate PDF file, you can do that with pdftk using the `burst` command option:

```
$ pdftk compilation.pdf burst
$ ls
compilation.pdf  pg_0001.pdf
pg_0003.pdf  pg_0005.pdf
doc_data.txt   pg_0002.pdf
pg_0004.pdf  pg_0006.pdf
```

QUICK TIP

The ocrmypdf utility exits with an error if the specified PDF file has already been OCR'd. You can use either the `--redo-ocr` or the `--force-ocr` command options in these cases.

The pdfinfo command can be used to view pertinent metadata information about a PDF file. The **dump_data** option with pdftk results in far more information.

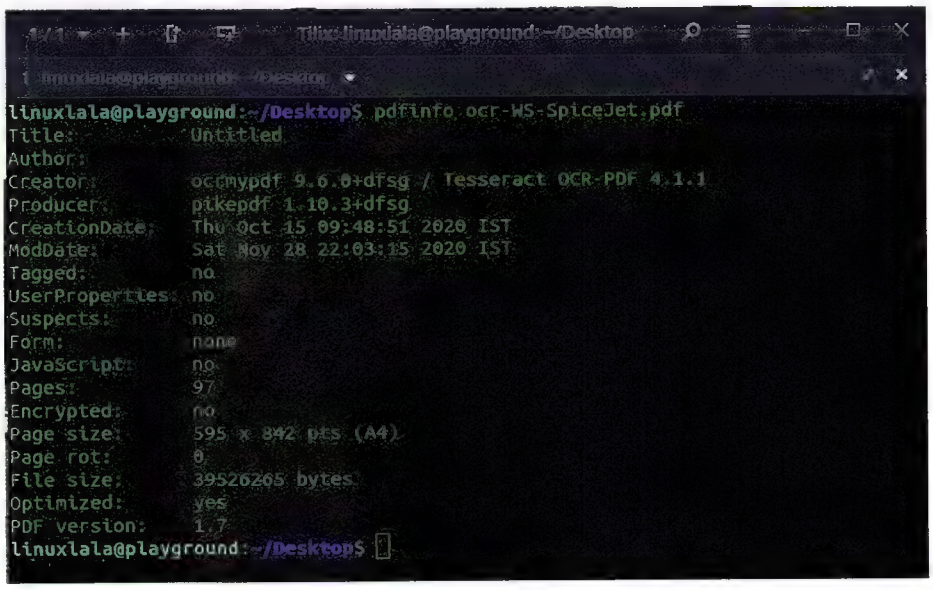
OCR my PDF

Optical character recognition (OCR) is a process that makes it possible to search, select and copy text from files such as scanned documents. Tesseract is one of the most popular open source OCR engines available for Linux.

The ocrmypdf utility utilises the Tesseract engine to perform OCR on PDF files. You can install it using your distributions software repositories.

Once installed, you can perform OCR on PDF files with the straightforward `ocrmypdf filename.pdf ocr-filename.pdf` command. The tool expects an input filename and an output filename for the OCR'd file.

You can also use the utility on OCR non-English PDF files, and perform various other operations. Refer to the man page, or run the `ocrmypdf --help` command for more information.



OPEN SOURCE MASTERCLASS

Use a Raspberry Pi as your daily driver

Christian Cawley eschews his usual laptop to discover whether the Raspberry Pi 4 can really act as a desktop replacement.

Much has been written about using a Raspberry Pi as a desktop replacement. When the Raspberry Pi launched in 2012, this seemed unfeasible. With the arrival of the 8GB Raspberry Pi 4, it is eminently possible.

Take the basic specification of a low-cost desktop PC from a well-known retail park supplier. The Lenovo IdeaCentre 3 is under $900 and features an i5 CPU, 5GB RAM, and a 1TB drive. Storage aside, there isn't anything to set that computer apart from a quad-core 1.5GHz Raspberry Pi 4. In many ways this is comparing apples and oranges, but it seems like the Pi is ready for "the big time." Of course, there's only one way to find out, which is why we've spent a working week using the Raspberry Pi as our main computer.

To clarify, every word of this feature has been written on the Raspberry Pi 4 8GB model seen in the accompanying photos.

Which Pi filling?

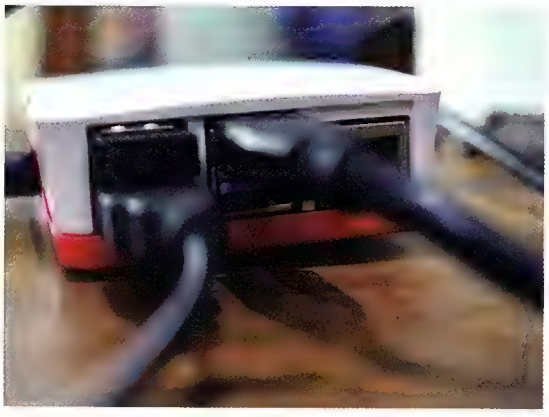
We've tried giving the Raspberry Pi a run as a potential desktop replacement since picking up the original Model B. All models since have spent time on our desk trying to substitute a desktop, attempting to run as a daily driver.

Only the Pi 3B+ and Pi 4 4GB have come close. Both have shortcomings, which is why the Pi 4 8GB raises the prospect of a Raspberry Pi solution that can make office productivity affordable for everyone. The Pi 400 is a potential option too, and with a similar spec to the 4GB model of the Raspberry Pi 4, it's a smart alternative if you don't have a suitable keyboard.

To ensure the effectiveness of a Raspberry Pi for daily work, we chose the model with the best specification, the Raspberry Pi 4 8GB.

This model measures 85.6x56.5mm, has Gigabit Ethernet, two USB 2.0 ports, two USB 3.0 ports and a USB-C power input. Two Micro HDMI ports for video output can support dual 4K displays, and there's a combined stereo and video port. 802.11ac wireless internet is available, compatible with 2.4GHz and 5GHz networks, along with Bluetooth 5.0 BLE.

QUICK TIP
The Pi 4 works as a daily driver. But if there's something you can't do with it, go and use your wheezing desktop and come back to the low-budget, environmentally friendly Pi.



With four USB inputs, the Raspberry Pi 4 can handle both USB 3.0 and USB 2.0 devices.

All the required connectivity options are available, ensuing easy plug-in of a mouse and keyboard, external drive, and anything else you might need. The best performance from a Raspberry Pi 4 8GB can be encouraged with the addition of heatsinks and a fan.

Your Pi needs

Before proceeding, some consideration of exactly how you use your PC or laptop is required before shifting to a Raspberry Pi. Advanced graphical or video work is probably going to be unsuitable (although worth further investigation). However, standard nine-to-five office tasks, programming, study and music playback are all easily achievable.

Unless you're using the Pi 400, you'll need a keyboard and a mouse. Almost any standard desktop input device you can think of should work out of the box, although wireless options might need a little tweaking.

Raspberry Pi OS is the perfect operating system for this purpose. While something like Puppy Linux/RasPup will give you the lightest possible desktop, an environment with all the tools you'll need already installed is best. So, the Raspberry Pi OS with desktop and recommended software option is ideal.

Timeline

Day 0

"Sensing that preparation would be key to the success of using a Pi 4 as my main computer for a working week, I spent Sunday preparing the system. This meant installing software, checking printer access and confirming key online resources worked. Fearing processing bottlenecks, I settled for the 8GB version of the Pi 4 and connected it to a spare monitor. A standard USB keyboard and mouse were attached, along with an external HDD for storage. This was to prevent overuse of the microSD card as well as to ensure any saved work could be retrieved in the event of a crash."

DAY 1

"Monday is almost always heavy on emails. Using Chromium, I was able to juggle several tabs, mostly email accounts and LinkedIn, without too much impact on performance. Meanwhile, LibreOffice Writer was my go-to program for producing this feature, as well as contributions to other publications and websites. Initial feeling: as effortless as using my HP laptop, just without the portability."

DAY 2

"The wired USB mouse started to irritate me. Each time I used it, the Raspberry Pi moved slightly. So I opted to connect a wireless mouse, but initial results weren't good due to lag. If this happens to you, fix it by disabling USB polling in **/cmdline.txt**.

sudo nano /boot/cmdline.txt

Scroll to the end of the file, then add:

usbhid.mousepoll=0

Press Ctrl-X to save the changes and exit, then reboot the Raspberry Pi.

Day 2 was the day my LastPass browser plugin worked. This saved time checking account credentials on my phone."

Raspberry Pi portability options

A standard Raspberry Pi might be lightweight and pocket-sized, but it's about as portable as a ball and chain. Desktop productivity in 2020 has the important dimension of flexible working, the ability to "hotdesk" and work from anywhere. This is something that a Raspberry Pi can't do without a battery and portable display. In fact, the more items you realise you need, the more cumbersome it becomes. Should you just switch to a laptop, or even a tablet?

Well, it's a smart alternative, but there's no reason to abandon the Raspberry Pi entirely. An increasing number of portable Raspberry Pi systems are available, from the Piper project box to the pi-top 3. Throw in things like the RasPad 3, a tablet-style Raspberry Pi with the option to hook up a USB keyboard and mouse, and various 3D printed solutions, and it's easy to see how easy it is to take your Pi with you.

Yet is it practical? Well, the answer really depends on what sort of productivity you're looking for. Coding, report writing, general office tasks... these standard computer uses should all be possible with a portable Pi system, although battery life may hold you back. The solution? Make sure you carry a high-capacity battery charger with you, to cover all eventualities.

For file storage, you might rely on the microSD card. However, this is probably not ideal in the event of your card being prone to errors. As such, a cloud or external storage device is recommended. As such, you'll need a good network connection.

One element that is easily overlooked is printer access. This is relatively straightforward to set up on the Pi. Start by installing CUPS

```
sudo apt install cups
```

Wait while CUPS and its dependencies install, then assign the default (pi) user administrative rights to CUPS with the following:

```
sudo usermod -a -G lpadmin pi
```

User pi is now a member of the lpadmin user group.

In the Pi's browser, open **https://localhost:631**. The browser will display a warning: Your connection is not private. Expand and click Advanced > Proceed to localhost (unsafe). The link, in this instance, is safe; you have installed CUPS, the port number 631 provides access to the CUPS server in your browser. Usually a browser displaying "Your connection is not private" is important, especially if you're browsing the web).

QUICK TIP
Popular desktop collaboration tools are hard to come by for the Raspberry Pi. While Slack has a desktop version, its browser interface is a smart alternative. For Asana, browser access is straight-forward, and easier to switch between multiple accounts than the mobile app.

Additional storage gives you fast file access and is useful if you intend to use the Raspberry Pi as a daily driver long-term.

If you're using a network printer, ensure it is switched on and connected to the same network as your Raspberry Pi. Otherwise, connect your USB printer to a spare port on your Pi and power it up.

In the CUPS interface, find Administration and authorise the pi user. Click Add Printer to prompt CUPS to search for your printer. Select the best option for your printer model. This may require some research, as some printer manufacturers don't provide Linux drivers for ARM devices. It's not unusual to repeat this stage several times until you find the right driver, so be patient.

When you're done, open a document in LibreOffice Writer and initiate a test print. If it prints as intended, you're ready to proceed.

Finally, identify any applications

Day 3

"Around 20 percent of my work involves sourcing and editing images. Websites like Pexels and Pixabay worked fine in the Chromium browser. But would the Pi be able to cope with the rapid resize and renaming of photos and screenshots?

Two options presented themselves: GIMP and Mirage. GIMP is a popular open source image manipulation tool, but felt like overkill for my purposes. So, after several days of deliberations, Mirage was installed. Using Mirage to crop and resize images is fast and efficient, and far less resource intensive than GIMP."

Day 4

"At least once a week I attend online meetings. Usually, Zoom, Google Meet (formerly Hangouts), and Skype are the tools used for this.

Fortunately, each of these services offer web tools that work on a Raspberry Pi 4 with little impact. The result: a meeting that took place with Google Meet, on a Raspberry Pi, seamlessly. For stability I opted to use a wired headset and mic, but otherwise the result was perfect, the usual unpredictable network issues aside. No one could believe that I was using a Raspberry Pi!"

Day 5

"Along with the usual word processing and spreadsheet tasks, the fifth day using the Raspberry Pi delivered a new challenge: uploading video from an SD card. I attempted this using a USB card reader. The drive mounted and the data was dragged to a sync folder on the Raspberry Pi. Copying the data took longer than expected. But speed aside, the task was completed, and the data uploaded. Meanwhile, my $1,600 laptop sat in a drawer, unaware that it was usurped by hardware totalling an eighth of its price."

you might need. Web tools are a good alternative where available, with most running perfectly in the Chromium browser.

Pi Ho, Pi Ho, it's off to work we go...

The next stage is to consider whether you need to install additional software. Using the standard Raspberry Pi OS, you'll find the Chromium browser, LibreOffice, and an email client preinstalled. Do you need anything else? Now is the time to install it.

For example, if you're going to require regular command line access then you might spend time installing guake, an advanced terminal app. For notetaking, the NixNote program is a smart open source Evernote client.

Of all the software in Raspberry Pi OS, the most important tool you'll have is Chromium. It now runs as well on a Pi as on any other device. This means that web apps that don't have installable alternatives for the Raspberry Pi can be accessed. Everything from Microsoft Office 365 to Slack, Zoom and Trello can be run in Chromium.

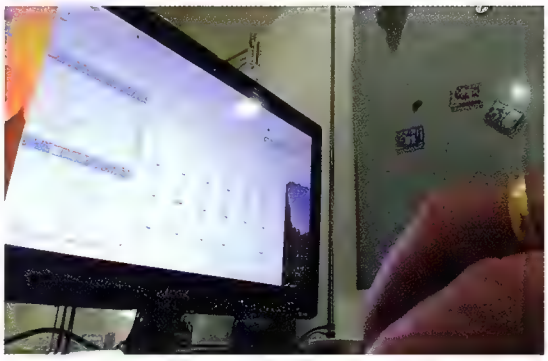
Working from home and concerned about privacy? If you usually access the web via a VPN you should install OpenVPN on your Raspberry Pi and consult your VPN provider's notes on OpenVPN support.

Lessons learned

While an overall successful working week was completed using the Raspberry Pi 4, it wasn't completely plain sailing.

Primarily, the lack of flexibility for a standard Raspberry Pi proved difficult. Limited to working at the dining table, other activities, from kids' homework to mealtimes, all impeded on productivity. Unlike most people, I had the option of switching to a RasPad 3, but this isn't an ideal solution. Further, it requires you to choose between transplanting the entire Pi into the RasPad case, simply swapping over the microSD card, or just switching your external storage to the alternative computer.

Other quibbles are less disruptive. Using Chromium is a smart idea, especially if you rely on Google services. However, while signing into the browser is a good option, you'll need to review the extensions you have installed as some will restrict functionality of web tools and even the Pi itself. Additionally, keeping browser tabs to a minimum for productivity tasks is wise.

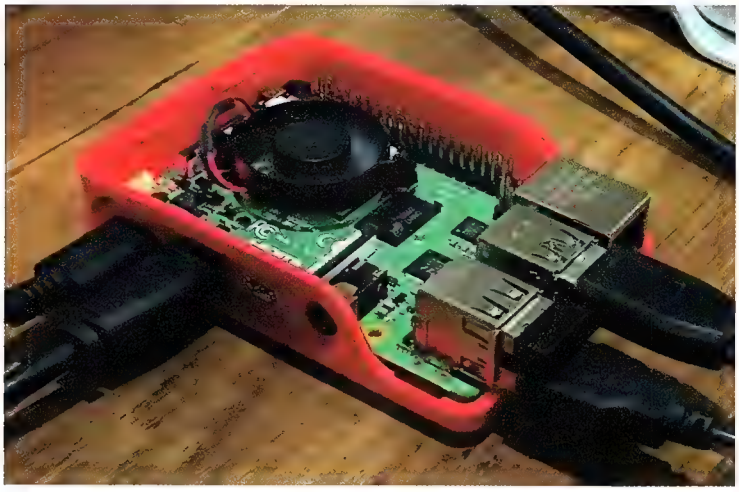


With a comfortable keyboard and mouse, the Raspberry Pi 4 can replace almost any office desktop computer.

Remember: we spent five days working on a Raspberry Pi 4 8GB. A model with less RAM won't yield the same results. For example, Slack won't run on a Raspberry Pi 3 B+ browser; syncing from cloud storage can be sluggish even on the Pi 4 2GB. Furthermore, regardless of which model of Raspberry Pi you use, the wrong keyboard and mouse can prove quite a barrier to productivity.

With five days of work completed, the Raspberry Pi 4 8GB has proved its competence as a desktop replacement. The idea of a sub-$120 computer setup that has the processing capacity to substitute a device for three times the price might seem unrealistic, but with almost a decade of development behind it, the Raspberry Pi is ready.

Sure, it's not going to replace a gaming PC, but it's more than adequate for office productivity, whether you're installed in a global corporation or working on your next coursework assignment.



The specification of the Raspberry Pi 4 8GB makes it particularly suited to use as a desktop replacement.

Choose a Raspberry Pi case

The Raspberry Pi boasts a range of cases across all device form factors. But only a few of these can be treated as productivity devices. For example, a Lego-compatible desktop replacement is less suitable than a case with space for a fan. Something that looks like a computer, rather than a toy, can subconsciously affect how you work.

Consider anything that looks tidy and uniform. The official Raspberry Pi 4 case ($14), for example, is a strong option. Alternatively, the Aluminium Armour heatsink case for the Pi 4 ($23) is geared towards performance. For something more like a traditional PC desktop, the Argon One Raspberry Pi 4 case ($49) resembles a small form factor PC. It also has the benefit of all port connectors being placed at the back of the case.

Expecting to need additional storage? Rather than plugging in an external hard disk drive, try a case with space for a 2.5-inch drive, or even M.2 SSD stick. The GeeekPi Acrylic Case ($13) has a SATA shield for a 2.5-inch HDD or SSD, available for both the Raspberry Pi 4 and the Pi 3. Raspberry Pi cases with space for additional storage should be given further consideration if you're planning on using the Pi as a daily driver long-term.

QUICK TIP

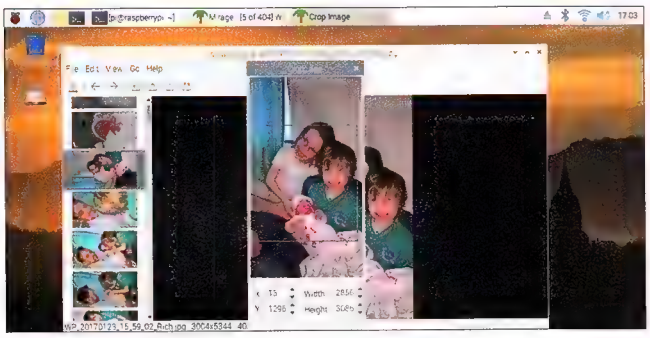
Mozilla Firefox might be a popular alternative, but if you're expecting to use your Raspberry Pi as a desktop replacement, Chromium currently offers the best support for vital web tools that you will need.

01 CHOOSE YOUR OS

Raspberry Pi OS with the full set of pre-installed software is the best option for a daily driver. It will save time later with all the productivity tools you'll need. While lightweight alternatives are available, the Raspberry Pi OS also features a well-supported version of Chromium, which you'll need for collaboration tools that are otherwise unavailable for the Raspberry Pi.

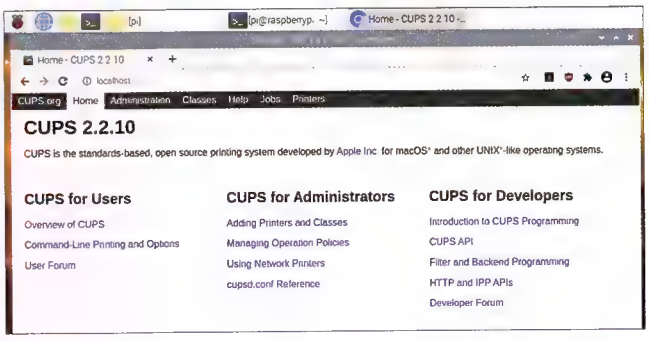
02 CONSIDER YOUR PERIPHERALS

Unless you're using the Pi 400, you'll need a reliable, comfortable keyboard and mouse for your new PC. Without stating the obvious, a display is also vital – there's no SSH-ing into your Raspberry Pi desktop replacement. For storage, consider an external hard disk drive for speed and convenience. Cloud storage is an option, although reliable sync tools for popular services are scarce.



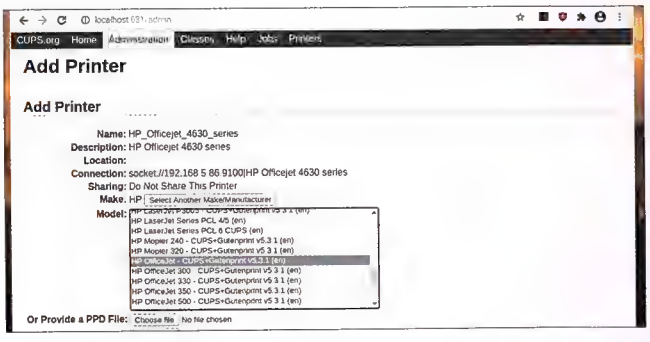
03 INSTALL ANY ADDITIONAL SOFTWARE

In most cases you'll have all the software you need pre-installed in Raspberry Pi OS. While web tools can be handled with Chromium, some applications will need to be sought out and installed manually. This might be something like a new terminal emulator or an image-editing tool. GIMP is preinstalled with the "full" version of Raspberry Pi OS, but Mirage is a simpler alternative that's still pretty capable.



04 INSTALL YOUR PRINTER

It's extremely likely that you'll need to print if you're using your Raspberry Pi as a desktop replacement. Start by switching on your network printer or plugging a USB printer into your Raspberry Pi and powering it on. Next, open a terminal and enter the following line of code: **sudo apt install cups**



05 CONFIGURE CUPS

With CUPS installed, add the pi user to lpadmin with sudo usermod -a -G lpadmin pi . Next, open CUPS in your browser with **https://localhost:631 and click Administration**. Select Add Printer, authenticate the pi account and then browse the list of drivers. Select the appropriate driver and initiate a test print to confirm.

06 TRIAL, ERROR, SUCCESS

Getting the setup of any PC right first time is unusual. But in the past the Raspberry Pi had a specific shortcoming: it just wasn't fast enough. This limitation doesn't exist with the Raspberry Pi 4 8GB model. If you have access to the correct programs, collaboration tools and data, the Pi 4 can replace your work PC, for a fraction of the price.

CPU COOLING

Darren Yates explains why your CPU gets hot, and the thermals at play you may not be aware of.

Top: Thermal Grizzly's Kryonaut rates as one of the best thermal pastes available.. Above: Noctua's NT-H1 has been around for years but still rates very highly.

CPU temps: how hot is too hot?

Ever since physicists William Shockley, John Bardeen and Walter Brattain invented the transistor in 1947, we've been making transistors bigger and smaller, faster and more efficient. Today, their form may be different but transistors still amplify the music in your phone, display the action of your movies and the games on your consoles. But no matter the application, the one thing every transistor does is dissipate excess power as heat and nowhere is this more crucial than in your PC. Pushed hard in gaming, encoding 8K video or mining cryptocurrency, the average PC CPU can dissipate enough power to drive six 15-watt LED light globes, so getting rid of that heat quickly enough to keep the billions of transistors inside your CPU happy and healthy is a science in itself.

Clock rate x voltage = heat

There are many factors affecting CPU temperature – from the size and number of transistors in the CPU, right down to the electrical characteristics of the transistors themselves. But in practice, the two key factors are the voltage the CPU operates at and the rate at which the transistors switch on and off – what we know as the 'clock speed' or 'CPU frequency'.

An important power management technique developed early on and still used today is 'dynamic voltage and frequency scaling' or DVFS. Electrical power consumption in this context is a function of voltage, current and the CPU frequency. By throttling back the CPU frequency and operating voltage on lighter workloads, CPU makers can reduce the instantaneous power dissipation. However, to achieve maximum performance, the CPU needs this voltage and clock frequency at their peaks – and there's where the heat is generated. If this heat isn't mitigated, the transistors will overheat and the CPU will fail.

How hot is too hot?

Which brings us to the money question – when it comes to CPU temperature, how hot is too hot? It's a common-enough question, but one that's difficult to answer. That's because like most things, it's not all black-and-white.

All modern CPUs have two key temperature ratings – the first is the case temperature (Tcase), which is measured at the metal heat-spreader your CPU cooling sits on. The second is the junction temperature (Tjunction) – this is the temperature at the transistor or CPU die level. All mainstream CPUs also include a sensor to monitor this Tjunction temperature. However, as all CPU families are different, not just in brand or architecture, but in manufacture, each CPU type has its own maximum Tjunction rating.

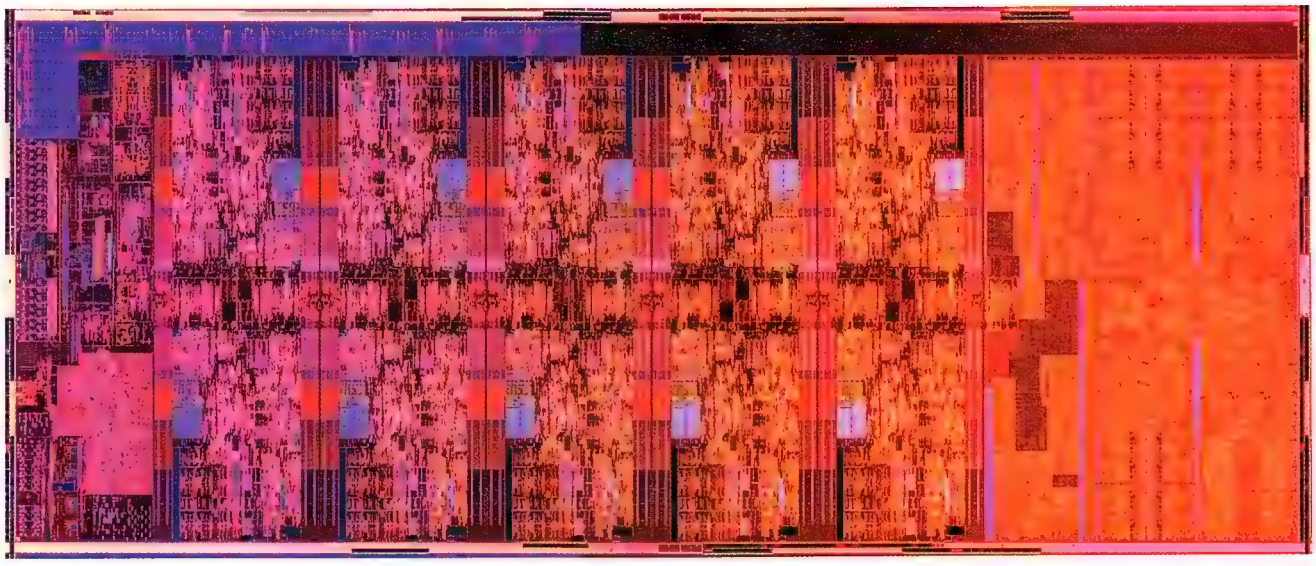
To find these temps on Intel CPUs, head to **http://ark.intel.com**, look up your CPU model, look for 'Package Specifications', then Tjunction or Tcase. For example, the old Core i5-2300 only lists a Tcase temp of 72-degreesC, whereas the Core i5-9400 has a Tjunction max temp of 100-degrees C. AMD lists 'Max Temps' on each CPU's individual spec page under 'Specifications'. For the Ryzen Threadripper 3990X, it's 95-degrees (**tinyurl.com/1tfw1lu5**). In general, Tjunction max temps are typically between 90 and 100-degrees C, but check your CPU manufacturer for your specific CPU. We'd also add the further below these temps your CPU stays, the better for its longer-term reliability.

AMD's Ryzen Threadripper 3990X has a thermal design power of 280-watts.

How does TDP relate to temp?

TDP or 'Thermal Design Power' describes the power a CPU will need to dissipate when running at 100 percent load at its design clock frequency. For phone CPUs, this can be as low as a couple of watts, for some Intel multi-core desktop CPUs, it can reach 130-watts (130W) and AMD's 64-core Ryzen Threadripper 39x0X CPUs can hit 280W. However, TDP itself is a poor alternative to determine maximum temperature because heat dissipation is also related to surface area.

This means a larger CPU can dissipate more power but at the same or very similar maximum junction temperature. A quick example – take Intel's Core i5-9400 above with its 100-degree C Tjunction temperature. It has a TDP rating of 65-watts (65W). Compare that with the Core i7-8700K – it also has a 100-degrees C Tjunction max temp, but a TDP rating of 95W. The AMD Ryzen Threadripper 3990X has a 280W TDP rating but a 95-degree C max temp. So, TDP tells you the heat dissipation you can expect, but nothing about the maximum temp ratings.



Top: Intel's 10th-generation Core-series CPU has billions of transistors. Above: Intel's Ark website provides TDP and temperature ratings for its CPUs. Below: William Shockley, John Bardeen and Walter Brattain invented the transistor in 1947.

Products Home › Product Specifications › Processors

Search specifications

Specifications

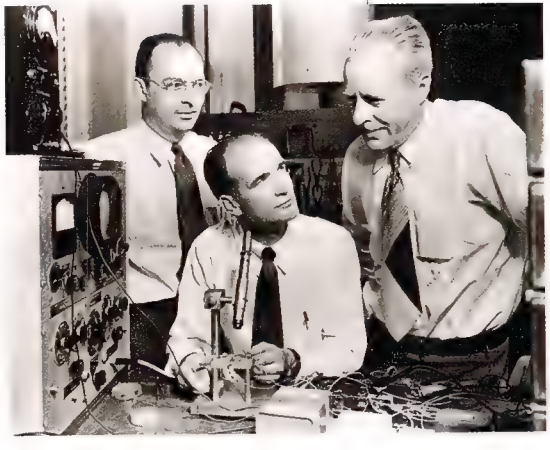
- Essentials
- CPU Specifications
- Supplemental Information
- Memory Specifications
- Processor Graphics

Package Specifications

Sockets Supported ?	FCLGA1151
Max CPU Configuration	1
Thermal Solution Specification ?	PCG 2015D (130W)
$T_{JUNCTION}$?	100°C
Package Size	37.5mm x 37.5mm

How does overclocking affect temperature?

It should be pretty straightforward that if you increase the clock speed and maintain (or increase) the CPU voltage, you increase the power consumption and the heat to be dissipated. The key with TDP figures is that they're the maximum-load power at the design clock speed. Overclock the CPU and you need to handle more power – this is why you might ditch the bundled cooler for something with more grunt-handling capacity.



There are two thermal transfer processes in a CPU – the CPU die to the heat spreader and the heat spreader to the CPU cooler. The first happens internally; the second you take care of.

But if you think the CPU cooler is the most important component, I'm here to tell you 'think again'. It doesn't matter how good your cooler is, if you do not have a sufficient thermal transfer interface between the heat-spreader and your cooler, your cooler won't be working at its best. This 'transfer interface' is the thermal compound or paste you see either already attached as a pad to the CPU cooler, or you buy separately in a small syringe.

The CPU heat-spreader and the base of your CPU cooler might seem perfectly flat – but they're not. The role of thermal paste is to 'fill in the gaps' to ensure a complete thermal connection between the two faces and minimise thermal resistance. So to get the most from your expensive cooler, don't skimp on the quality of the thermal paste. And remember, just a thin film over the heat-spreader - you're not slapping on sun-screen.

How do I know if my PC is running hot?

Intel lists a number of factors to look out for if you suspect your PC is overheating. These include the PC shutting down for no apparent reason, the cooling fan running continuously at high speed and the CPU clock rate being less than expected. DVFS is the CPU's first line of defence to reduce power consumption and keep the Tjunction temp below maximum levels. If that fails, that's when an apparently-random shut-down will kick in as the back-stop defence mechanism to prevent thermal damage.

Transistor power dissipation has been an issue since 1947 and the same principles also apply to CPU cooling. Removing heat as efficiently as possible will help ensure it gives you a long life of high-speed processing.

PIC: 1984, TAITO

SPECIFICATIONS

CPU: Zilog Z80A @ 3.579 MHz **RAM:** 8-128 KB plus 16 KB of VRAM **ROM:** 32 KB BASIC **Graphics:** Texas Instruments TMS9918 with 16 colors, 256x192 maximum resolution, single colour sprites **Sound:** General Instrument AY-3-8910 PSG **Storage:** Cartridge, cassette, 5.25in and 3.5in inch floppy add-ons **OS:** Microsoft BASIC and MSX-DOS **Released:** June 1983 **Production:** 1984–1992 **Worldwide sales:** 5 million

MACHINE OF THE MONTH

Microsoft MSX architecture

A valiant attempt to create a common 8-bit standard.

This month's computer is a little different. Rather than being a single system, MSX was actually a Microsoft specification for eight-bit microcomputers. Countless brands produced their own MSX machines, which dominated Eastern markets. The MSX era is a fascinating period of computing history often neglected in the West, which showcases an unusual stage of gaming evolution.

Japan in the early 1980s was flooded with home computers. Despite most machines sharing Microsoft BASIC, these computers were usually incompatible with each other. In June 1983, Microsoft announced the MSX specification: an attempt to standardise eight-bit microcomputers into a unified architecture. Rather than being an invention of Bill Gates, the MSX standard was actually the brainchild of Kazuhiko Nishi, the vice-president of Microsoft Japan and director of ASCII Corporation. Inspired by the VHS video standard, if software could work on one MSX machine, it should be able to work on any other.

The standard was designed around the Spectravideo SV 328, largely because it was built with off-the-shelf parts, and used Microsoft BASIC for an operating system.

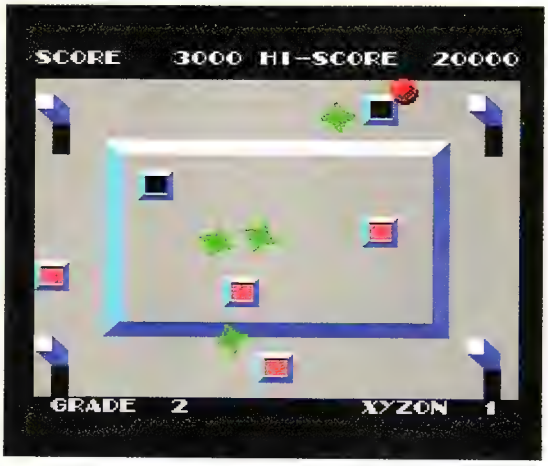
It's unclear what MSX actually stands for. It's believed to mean either Microsoft Extended, or Machines with Software Exchangeability – though Nishi hinted that it may also refer to the MX missile!

Hardware development

Primarily, any MSX machine needed a Zilog Z80 CPU and a Texas Instruments TMS9918 graphics chip with 16KB of VRAM, plus several standardised I/O chips. Beyond this specification manufacturers were free to do as they pleased, and all major Japanese manufacturers released machines, with some wildly varying form factors.

RAM ranged from 16-128KB, though 64KB was the most common. Streamlined chipsets were common in budget models, and there were numerous cartridge-based add-ons. Instead of rubber chiclet keys, MSX computers usually had proper keyboards and arrow keys, which increased costs. Software usually came on either cartridge or cassette. Although disk drives were available, they weren't common until the MSX2.

We especially liked *Xyxolog*: an interesting physics arcade game with *Marble Madness* elements.



Gaming

MSX gaming was a strange world of in-betweens. Even though games often featured impressive environments to match the consoles, the machine's single colour sprites looked like something from a cheap British micro.

MSX computers also had a console-style cartridge slot, which unlike Western micros was actually used by most games. Therefore games could often load instantly, and use a combination of the keyboard and joystick.

Most Japanese MSX games come from between 1983 and 1987 – the Japanese were quick to move onto the MSX2 – and usually on cartridge. European and South American titles extended into the early 1990s, mostly on tape, or less commonly on disk.

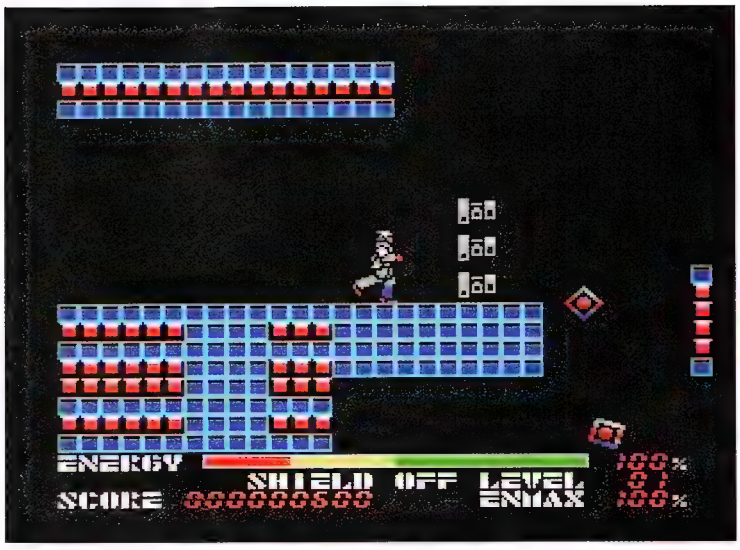
The underlying MSX hardware was similar to the Sega SG-1000, and many MSX titles were Sega ports. Arriving before Nintendo's Famicom (or "NES"), the MSX was Japan's platform of choice before Nintendo's eventual dominance.

Gaming giant Konami was particularly famous on the system, and series like *Bomberman* and *Parodius* got their start on the MSX,

PICS: WIKIPEDIA, 1986, GAME ARTS

"In June 1983, Microsoft announced the MSX specification: an attempt to standardise eight-bit microcomputers into a unified architecture."

well before arcades or consoles. Other MSX classics include *Kung-Fu Master*, *Penguin Adventure*, and *1942*.



Thexder is an all-time classic that seriously shows off the power of MSX, with impressive gameplay and proper scrolling.

Legacy

Even though the MSX wasn't popular in the US, Australia or the UK, the MSX was the machine of choice in Japan, South Korea, Brazil, and Argentina. In Japan, MSX machines were dominant through the 1980s, until PCs finally became cheap enough to end their reign. By the time the MSX was discontinued, at least five million units had been sold.

The MSX was followed by 1985's MSX2, as well as the MSX2+ and MSX Turbo R – machines we will explore in future issues.

Emulation

Emulating the MSX isn't entirely straightforward. If you only want to play classic cartridge games, that's easy enough. But if you want to run software from tape or disk, or use BASIC, then everything becomes more complicated.

Multi-purpose emulators like RetroArch and MAME require BIOS ROMs in order to work, so you may as well use an MSX-specific emulator. There are two main choices: fMSX and openMSX. fMSX is bad at running cassettes, and openMSX is bad at running disks. Cassette software was more common for the original MSX, and openMSX works better across platforms, so we'll focus on that.

Installation and usage

For Windows users, head to **https://openmsx.org** where you'll find the Download section in the navigation bar on the left. There are both 32 and 64-bit versions available, with the choice of "install" or "zip." Grab the "install" version. It comes with an MSI installer, which is compressed in a ZIP file, so you'll need to open or extract the ZIP f ile first and double-click the installer file.

Follow the prompts, and openMSX should be available in your system menu under Programs > openMSX > openMSX.

For Linux users, openMSX should be available either in your distro's repository, or you can use the Flatpak available at **https://flathub.org**.

Once launched, openMSX is fantastic for quick and easy gaming – joysticks are automatically detected, and an excellent scanline mode is enabled by default.

To get started, ignore the no-cartridge error message, and move your mouse pointer to the top-left of the window, where a menu button will appear. Choose "Load ROM… (slot A)" from the top of the new menu, and in the file browser pick your .rom cartridge.

And that's it. If you don't have a joystick, most games use the arrow keys for movement, and Space to fire. Alt+Enter toggles full-screen mode.

Disks and cassettes

Unfortunately, openMSX's open-source ROM only supports cartridge games – you need to provide a BIOS image for cassette functionality. These are still copyright protected, though are illegally available on ROM sites; the openMSX documentation provides instructions on how to legally obtain ROMs.

If you want to use disk images or BASIC, try fMSX, which supports both out of the box. It comes with cassette support, but it rarely works.

If you do have a BIOS, then for Windows, copy the files into My Documents/openMSX/share/systemroms. For Linux, copy the files into ~/.openMSX/share/systemroms.

BIOS wise, we found that "MSX System v1.0 + MSX BASIC UK (1983)" and "MSX System v1.0 + MSX BASIC Japanese (1983)" both gave us a good selection of working machines.

To get started with cassettes, you need to launch openMSX Catapult, which should be under the same menu as openMSX. Once inside, run File > Test MSX Hardware to scan for local ROMs. Anything that openMSX recognises will then be added to its menus of usable hardware.

Once the scan is finished, you can select a machine from the "MSX type" menu. Anything with "C-BIOS" is an open-source replacement, so choose one of the other available entries, presuming that you provided a recognised ROM.

To specify a tape image, click the "Cassette" button in the "Cassette Player" field, and choose "Browse cassette image." Select a .cas tape image, then click "Start" at the bottom of the window. OpenMSX should automate the loading process and run your tape image.

If you still want to try disks with openMSX, it recognises the Digital Design Electronica DDX v3.0 ROM, which is an add-on you can enable in the "Extensions" menu. You can browse for .dsk files in the same manner as cassettes.

JOHN KNIGHT ■

YOU'LL NEED

OPENMSX

For this tutorial, grab openMSX, which is available on Windows and Linux in both 32 and 64-bit versions:
https://openmsx.org
For advanced users who want BASIC or disk usage, try fMSX:
https://fms.komkon.org/fMSX

Fresh *Grand Theft Auto* trilogy remaster rumours surface on Rockstar's forums

Over on Rockstar's official GTA forums, fans have been discussing the topic of future DLC. The topic was started in November 2020 but it's still enjoying a healthy discourse to this day, and, more recently in January, one member who is listed as Machlbud – and is known for having leaked credible information in the past – swung in and commented the word "Soon".

Metro Exodus is getting a PC *Enhanced Edition* as well as other additional upgrades

Metro Exodus is getting a free *Enhanced Edition* upgrade which is set to release as soon as this Spring. According to a statement released on Steam, *Metro Exodus*' 4A Engine will be receiving an overhaul which will result in various visual improvements. This update comes shortly after the announcement that a *Metro Exodus* next-gen version is on its way.

GAMING NEWS

Resident Evil Outrage may be the third installment in the *Revelations* series

...and it may release early next year.

Resident Evil Outrage is a new game in the Revelations sub-series and will release "within a year" of *Resident Evil Village*, claims a leaker with a decent track record. That leaker is Dusk Golem, who correctly reported on *Resident Evil 8* ahead of its reveal, among other things.

In tweets sent last month, AestheticGamer, aka Dusk Golem, claims the game will be a timed Nintendo Switch exclusive before appearing on other platforms. That makes sense, as the first *Revelations* game was initially a Nintendo 3DS exclusive. The tweets claim *Revelations 3* will land either late this year or early next and will release as part of the series' 25th anniversary celebrations.

Dusk Golem claimed *Outrage* will have a "higher budget and a lot more dev time" than the first two *Revelations* installments. Due to its higher budget quality, the leaker claims Capcom may consider ditching the *Revelations* tag altogether.

E3 2021 won't go ahead

But it may be getting a digital alternative.

The COVID-19 pandemic put most games conventions out of action in 2020, and it looks like the same will happen this year. The world's biggest trade and consumer convention, E3, is the most significant to go on the chopping block so far in 2021, with City of LA documents confirming that the live event has been cancelled.

According to that document, the City of LA is "working with production teams on broadcast options at LA Live/LAAC (LA Convention Centre)," suggesting these venues may still be used to create a digital version of the show.

The ESA, which organises E3, confirmed in February that it would hold a digital-focused show, with the possibility of a scaled back live show to coincide. Whatever the case, with major publishers now opting to host their own digital hoedowns, it'll be interesting to see whether E3 has much more life in it.

Development on *Anthem* has ceased

The failed GaaS title was previously being revamped.

Despite great launch window sales, *Anthem* was a mess upon launch in 2019. It was famed RPG studio BioWare's attempt to build a *Destiny*-styled 'game as a service' shooter, but it failed to redeem the studio after its equally-disappointing *Mass Effect: Andromeda*. In 2020, BioWare announced it would relaunch the game as *Anthem Next*, which would entail a full scale revamp of the game. But that's no longer going to happen.

In an announcement last month, BioWare Austin studio director Christian Dailey broke the news, confirming that while *Anthem Next* won't be happening, the game's servers will still operate.

"2020 was a year unlike any other however and while we continue to make progress against all our game projects at BioWare, working from home during the pandemic has had an impact on our productivity and not everything we had planned as a studio before COVID-19 can be accomplished without putting undue stress on our teams," Dailey wrote. ""I know this will be disappointing to the community of *Anthem* players who have been excited to see the improvements we've been working on. It's also disappointing for the team who were doing brilliant work."

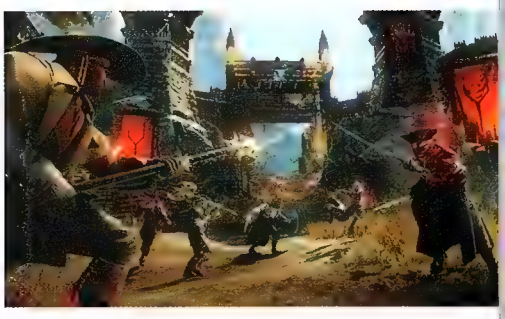
Sony is bringing more PlayStation games to PC

Following *Horizon Zero Dawn*, *Days Gone* arrives soon.

While Microsoft has all but given up on console exclusivity, Sony and Nintendo are still protective of their first-party offerings. While that's likely to remain true for Nintendo in perpetuity, Sony is slowly opening the floodgates, with president and CEO Jim Ryan confirming that month that more is coming. The next game, following *Horizon Zero Dawn*'s arrival on Steam last year, is *Days Gone*.

"A few things changed," Ryan said. "We find ourselves now in early 2021 with our development studios and the games that they make in better shape than they've ever been before. Particularly from the latter half

of the PS4 cycle our studios made some wonderful, great games. There's an opportunity to expose those great games to a wider audience and recognise the economics of game development, which are not always straightforward. The cost of making games goes up with each cycle, as the calibre of the IP has improved. Also, our ease of making it available to non-console owners has grown. So it's a fairly straightforward decision for us to make."



Amazon's MMO *New World* gets a third delay

Amazon Game Studios has delayed its upcoming MMORPG *New World* once again, this time pushing it to August 31, 2021. *New World* was previously delayed from May to August 2020, and it was more recently pushed to spring 2021. Compared to its second delay, this move to August 31 is comparatively small. Amazon is also speaking in more specific terms with regards to dates and time frames, so while this isn't necessarily the game's final delay, it seems that *New World* is coming into some form.

"We've been hard at work on compelling end-game features we believe are important to include."

Official Xbox Series X wireless headset released

Microsoft has announced a new Xbox wireless headset for its consoles which can also be used across PC and mobile devices. Microsoft revealed the Xbox Wireless Headset in a blog post, with the developer saying that the new headset "delivers best-in-class audio and chat performance." While it's been designed to match the appearance of the Xbox Series X and Xbox Series S, it'll work across Xbox One consoles, as well as with PC and mobile games.

More than just working with your phone, however, the headset will pair with your mobile at the same time as your console, allowing you to chat to a friend without disrupting your game. Microsoft also points out that that means you can play during a conference call, but personally I would advise against that if you don't want to risk upsetting your boss.

$75.95 | PC, PS4/5 | bit.ly/pcgnioh2

Nioh 2: The Complete Edition

It's a yokai for a yokai.

Stumbling into the first boss after slashing through a riverside village beset by demons, I begin to chip away at a screen-dominating health bar with my looted purple ninja knife. Little falls off before it roars, plunging me into a dark world and then summarily killing me with its saw-bladed cleaver. "Yeah, yeah," I nod, "I've played *Dark Souls*, I know you're not meant to be able to beat the first boss. It's just flavour." Then I respawn, and realise this is just the start of the mountain to come after all.

The large arsenal of possible weapons aren't your only tools for spilling hot yokai blood. Your custom character is half-yokai themselves. Not only does this mean you can spend ameter to enter a powered-up state of demon-slapping fury, but also that you can harvest the powers of defeated enemies to use yourself in battle. Having access to these super moves is a surprisingly fresh twist on the rock-solid genre, giving you the option to literally press a 'whack it with a giant hammer' button if you just want to dish out some easy damage and take a breather. A Burst Counter even gives you the option to parry boss attacks and knock them off balance.

The backdrop for all this slaughter is Japan's Sengoku period. A time of bloody war, it's a great excuse to send you across Japan. Though the real world setting can feel a little repetitive compared to the fantasy vistas of the *Souls* games. You'll see a lot of forests, caves, shrines, and forts. Even so, each distinct level is masterfully crafted, multiple paths weaving together alongside shortcuts to Kodama shrine checkpoints (*Nioh 2*'s brand of bonfires, where you revive sans your re-collectable upgrade currency when you croak).

There's plenty to see, as the game easily took me about 70 hours to beat. Besides main missions it has plenty of side content, reworking previous maps into new challenges that feel fresh. And that's not to mention the three pieces of bundled DLC that add even more. Little else in the genre has such satisfying gameplay, but there's a limit to how much repetition you can avoid in a game this long.

apc RECOMMENDS

Thanks to the quickfire stance shifting and pulse timing, playing this on keyboard is the domain of those who love to touch type business emails directly into cryptographic ciphers. There's some noticeable pop-in on some far off enemies, and some environment textures look a little dated today, but the character designs and effects are right on point, and its in-depth photo mode is one of the best around. This is a game focused around performance, and it certainly delivers.

OSCAR TAYLOR-KENT

Raising the genre highbar, *Nioh 2* runs and plays beautifully. But perhaps you can have too much of a good thing.

★★★★☆

$54 | PC, PS4/5, XB1, XBS/X | werewolf-videogame.com/en

Werewolf: The Apocalypse – Earthblood

An old-fashioned brawler with teeth.

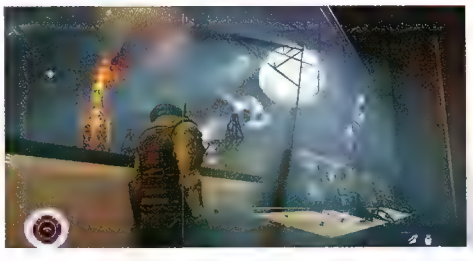
This is not a game to wow somebody who happens to walk past while you're playing. The character models have arrived fashionably late from 2010. Still, *Werewolf: The Apocalypse – Earthblood* is re-freshingly keen to throw you straight into the action. The game starts off with a chat between you and a few members of your pack regarding your plan to sabotage a nearby fracking site. And twenty minutes or so later, you've inhabited all three of hero Cahal's forms, most of the game mechanics have been introduced, and sufficient drama has taken place to kick off the next leg of the plot.

The story jogs along like this until the end, which works very well. Whether gameplay itself hurtles along without pausing for breath is up to you. The bulk of the game is made up of fairly small areas full of enemies and, fundamentally, it's all about making your way to the exit so you can enter the next area. This is where the cool ability to change forms comes into play.

If you're careful, you can make your way through a surprisingly large amount of the adventure without engaging in combat. While I give myself a pat on the back each time I successfully escape unseen, more often than not I get caught sneaking across the floor like a guilty child with their hand in the cookie jar, which I think is the best way to experience the game. As soon as I get hit I automatically transform into the third, most powerful, form used for combat.

Combat is arguably over-simple, and rarely a challenge on any difficulty. The inability to backtrack or create multiple saves means the rare instances of choice are one-shot deals. Yet I've played this game from start to finish twice, and enjoyed it both times, which counts for a lot. It's a B-movie experience in the best possible way; not so bad it's good, but so determined it's good.
LUKE KEMP

Mixes stealth with action, and the fun doesn't snag on the rough edges.
★★★½☆



Free | Browser
bit.ly/RaindropGame

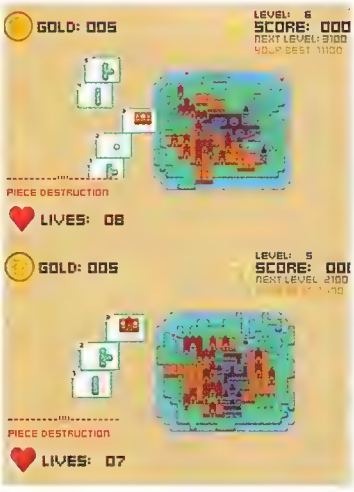
Raindrop

They keep falling on your head.

True to its title, your goal in *Raindrop* is a fluid one. It's a (seemingly) simple arcade-style game in which you play as a cat, avoiding falling rain. On a basic level, you have to run across the corridor of an elementary school, making repeated trips in your daring quest for delicious points. It has a very leaky roof, however, and a single drop is all it takes to wet the cat and end the game, so you also have to dodge an increasing number of plinking raindrops. Where *Raindrop* differs from most arcade games is in its free-form scoring system.

For instance, by hanging around to collect the bouncing stars you'll increase your score when you reach the exit door, but you're also rewarded for speeding straight across the hall without stopping. You can combine these two approaches, or seek out the more hidden objectives, some of which are so lightly teased that I felt like a genius when my theories were proved correct. *Raindrop*'s focus on playfulness and experimentation is quite unlike any arcade game I've played.
TOM SYKES

Play *Raindrop* any way you like, with speed or with caution. Just play it, because I've found so much joy in doing so.
★★★★☆



Free | Browser | solroo.itch.io

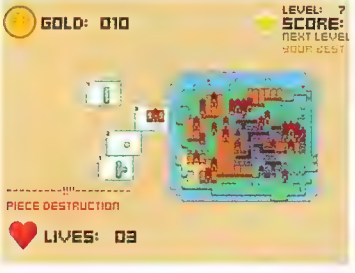
Kingdom Tetris

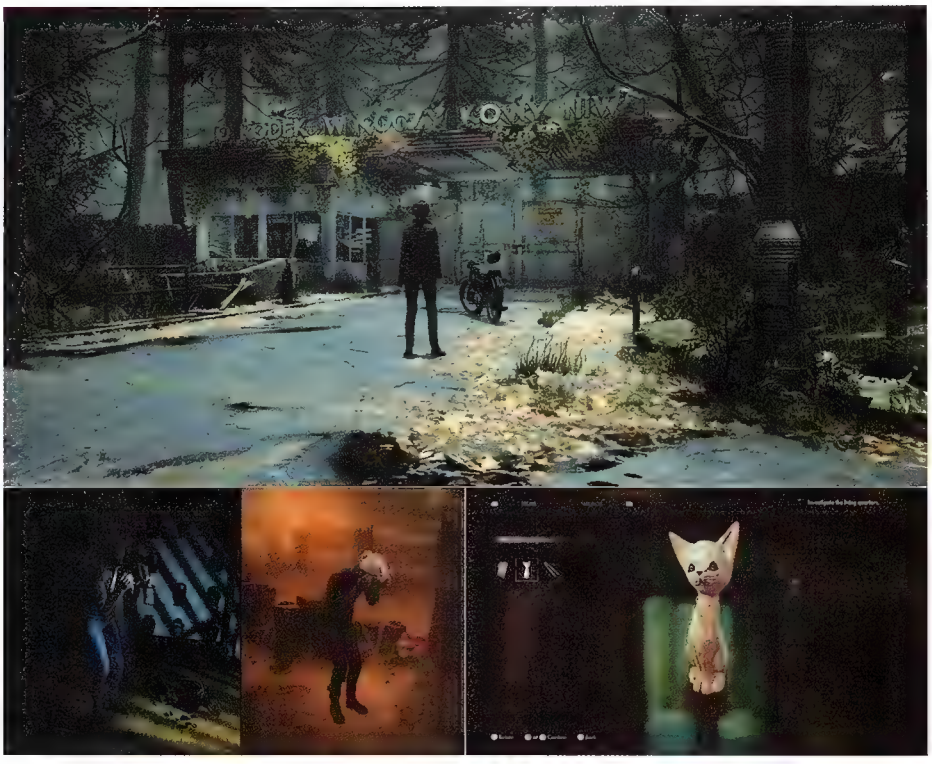
Fit for a king?

City planning has come on a long way since people fussed about with pencils and maps. Now it's all done with *Tetris* blocks, meaning the constituent parts – land, castle pieces, houses etc – fall from the heavens, pre-constructed. All you need to do is pluck them out from the air and slot them down on the jigsaw earth. It's incredibly stressful – but your settlement will be completed in record time.

It's a left-field idea, combining *Tetris* with a medieval kingdom builder, but they're two concepts that blend together nicely. You're trying to expand your tiny realm from an islet with a castle on it to a great big island with a sprawling castle, woodland, crops, and houses, although you have very little time to think about the layout. Really you're jamming *Tetris*-shaped land pieces wherever you can shove them, then plonking settlement bits on any free space on top of them. Every so often, if you're good enough, the screen will expand to let you shift the borders of your kingdom and use more pieces.
TOM SYKES

I could probably love *Kingdom Tetris*, if it was about 50 percent easier, or it had an easy mode.
★★★☆☆





$75.95 | PC, XBS/X | blooberteam.com/the-medium

The Medium

Ferries third-person horror into a new life.

The Medium plays like an old-school *Resident Evil* game, minus the gunplay. You navigate Marianne around crumbling, abandoned hotels and claustrophobic Cold War bunkers from fixed camera angles. It can be a bit cumbersome, but it's a deliberate and effective design choice. *The Medium* is excellent at making you feel like you're always being watched, and that danger could be lurking just out of view at any time.

The added gimmick here is that Marianne can sometimes see into the spirit world, which is handled by splitting your screen in half, down the middle. All inputs will affect the real and spirit world versions of Marianne identically, but there are often small differences in the terrain or enemies that only exist in one world or the other to complicate things. Unfortunately, Bloober Team definitely didn't push this idea to its limits. Most of the puzzles are fairly simple, and there were only a couple of those *Portal*-like 'a-ha!' moments that made me feel like I'd done something really outside-the-box and clever.

The star, though, is the story. *The Medium* is exquisitely paced and plotted, with a complex, but not convoluted, supernatural mystery to uncover. It kept me guessing throughout, but the big reveals always felt earned and well set up. I had several running theories about what was going on at the haunted Niwa Resort that all made sense, but the true answer ended up be-ing even more elegant and poignant than I guessed. And yet it doesn't seem to come out of left-field, M Night Shyamalan-style. It's some of the sharpest writing I've seen in a videogame in a long time.

Despite some technical foibles and the simple, unchallenging stealth and puzzle solving, I fell completely in love with *The Medium*. The writing stacks up to the very best in the genre with its well-crafted mystery that explores difficult, often very relatable themes on its way to a satisfying, though not uplifting conclusion.
LEANA HAFER

A sharply written, thoughtful, and emotional horror game with a clever mind-twisting gimmick.
★★★★☆

$42.95 | PC | slitherine.com/game/field-of-glory-ii-medieval

Fields of Glory II Medieval

A solid but safe tabletop-style treat.

This is a wargamer's wargame. There's no nice music. The graphics are barebones. The UI is pretty basic. You'll want to memorise hotkeys. What there is are 50+ hours of historical scenarios and campaigns. The famous battles give you a prearranged battlefield and let you pick a side, then customise it a bit. The campaigns give you good context on a fixed route while still letting you make decisions about your army's composition.

Multiplayer is handled in the same asynchronous style as past *Field of Glory* games, which is disappointing and frustrating if you want to finish a match in one sitting. It's just functional enough if you can only sit down to play for 15 minutes at a time. Very unimpressive and underwhelming.

FOG II: Medieval's battles focus on historical simulation over clever or puzzle-like tactics scenarios. It delivers that in spades, with the kind of battles a history buff salivates over. They're dynamic and unpredictable, forcing you into surprising scenarios when troops unexpectedly flee or the enemy makes a surge. You use those rules to take an array of historical factions through the scenarios.

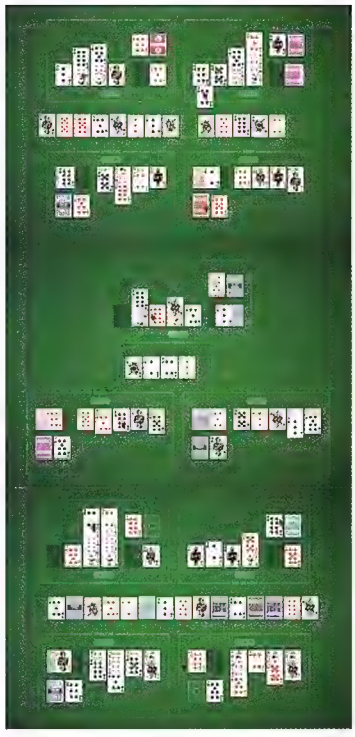
Battles take a long time to play because they're a medieval meatgrinder. Troops lock each other into melee, only sometimes falling back or escaping from that melee due to morale breaking or combat results – neither of which are something you particularly have control over once the brawl begins.

That aside, some of the game just doesn't feel properly medieval. The time period starts at 1040 and runs to 1270, stopping just short of the grandiose 14th century finale of armoured knights, longbows, and mercenary crossbowmen. The ruleset's emphasis on flanking manoeuvres over numerical advantage makes a lot of sense in the ancients period, but it feels silly when three units of elite infantry can't make a squad of enemy recruits flee in a single simultaneous assault.

JON BOLDING

The closest to a tabletop miniatures experience that you'll get on the PC.

★★★☆☆



Free | PC, Mac, Linux | bit.ly/3dhDFeO

Nerts! Online

Compelling trial by fire.

Zachtronics' latest release is, surprisingly, a version of the card game *Nerts!* – a real-time, competitive game where players have to frantically shuffle, sort, and clear their own decks of playing cards. *Nerts! Online* is a relatively skeletal adaptation, but the team has focused on the right things by creating a tactile, speedy card game.

This is a multiplayer-focused game that you'll either play online with chums or strangers. I learnt the rules, and played a few practice games to get the hang of things, but even so, this has been an embarrassing – albeit enjoyable – trial by fire. I'm gradually getting faster, and I think I will continue, as there's a real sense of community around this unassuming game.

It's a slick and accomplished adaptation of an obscure game, but it's also a small, silly thing – a Zachtronics in-joke that got released to the wider world. There are no microtransactions, no player records, none of the bumf of the modern multiplayer experience. And it's all the better for that sense of purity and focus.

TOM SYKES ■

Simple time-passer with a friendly and welcoming community.

★★★½☆

These guys are not happy about me using noclip.

DEVELOPER ID SOFTWARE **PUBLISHER** GT INTERACTIVE **RELEASED** JUNE 22, 2016 **WEB** IDSOFTWARE.COM

QUAKE

The blueprint for 3D shooters has lots to teach in 2021.

A wizard lives here, supposedly. Either he's out to lunch, or someone at id Software in 1996 came up with the name for *Quake*'s E2M5, 'The Wizard's Manse', and decided it was too cool – sorry, too metal – to change, even when the wizard himself never makes an appearance. Forgivable, considering it's one of the most tightly crafted levels in a game full of them.

I've been on a classic first-person shooter tear recently, playing a mix of old-old and designed-to-feel-old shooters like *Amid Evil*, *Dusk*, *Duke Nukem 3D* and *Quake*. With so many games today designed to keep you playing for a hundred hours, it's refreshing to pick up a shooter that lets you ice skate uphill at Olympic speeds and tear through a dozen levels in an hour or two. But with *Quake*, it wasn't really the speed that pulled me in. Even closing in on 25 years old, *Quake* still surprisingly feels like a game with a surprising amount of wisdom (though again, no wizards) to offer.

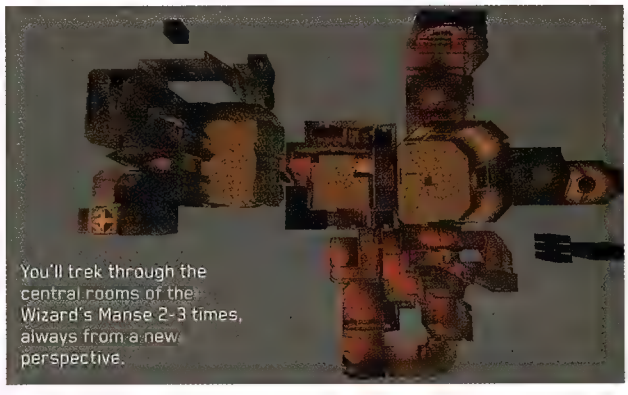
It's simple wisdom, really, but few shooters have outdone id's level design even with two decades to study them. Here's a basic lesson *Quake* imparts in The Wizard's Manse: climbing up a staircase and realising that you're now standing on a platform above the room you fought through a few minutes ago is more empowering than any shotgun. It's a perfect videogame moment, closing the loop on the thought 'how do I get up there?' with the sudden satisfaction of doing it without you even realising it.

Another *Quake* lesson, which goes hand-in-hand with that one: a small level is almost always more impressive than a big one. The Wizard's Manse is about a dozen levels into *Quake*'s campaign, and was the first one to really make my lizard brain stop and pay close attention. John Romero once tweeted it's his favourite level in the game, and I can see why: E2M5 channels id's excitement with three dimensions into an intricate construction of criss-crossing walkways, looping back over itself twice before you reach the end.

Brown notes

It's so easy to chew through these old shooters without really stopping to look around. And in *Quake*, there's usually not a whole lot to look around at. A few levels borrow

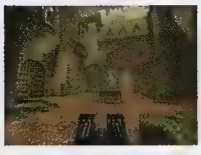
Even fiends gotta do their calisthenics.



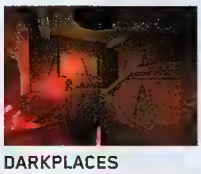
You'll trek through the central rooms of the Wizard's Manse 2-3 times, always from a new perspective.

QUAKEFUSION What in hell is the best way to play *Quake* today?

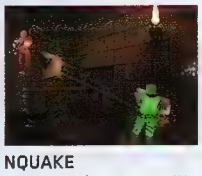
DOS QUAKE
On Steam and GOG, minus the soundtrack. A guide on Steam can help you restore Reznor's tunes.



QUAKESPASM
A modern *Quake* engine that hews closely to the original, but adds hi-res and hi-refresh support.



DARKPLACES
An engine rewrite with HD textures and real-time lighting, and compatible with many mods.



NQUAKE
When you're done with the single-player stuff this is the go-to for multiplayer *QuakeWorld*.

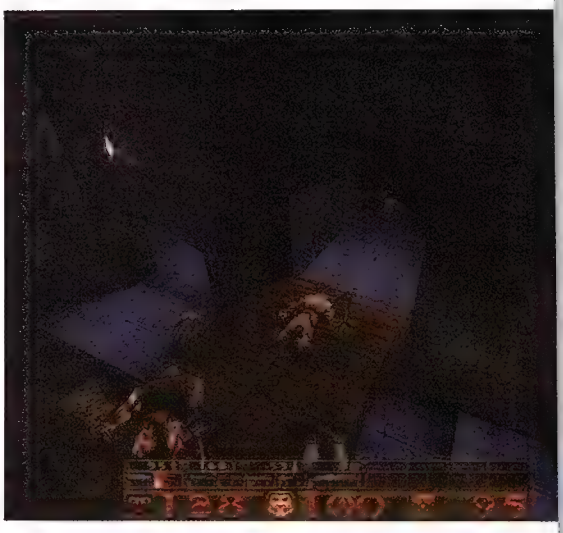
Doom's sci-fi aesthetic, but each episode invariably descends into a vaguely Lovecraftian castle or dungeon. *Quake*'s defining characteristic is the colour brown. Even the water is muddy.

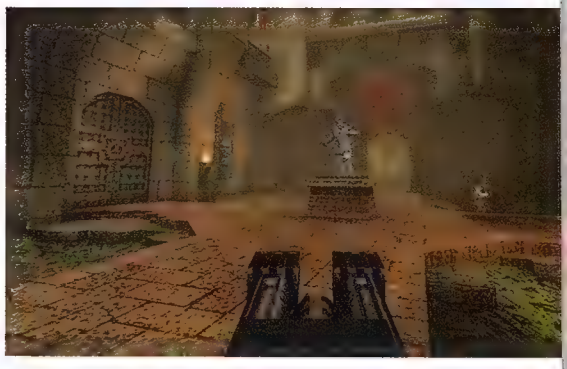
Doom is favourably remembered for its amazing maze-like levels, while *Quake*'s campaign is mostly remembered for what it wasn't: the more RPG-esque fantasy adventure that John Romero wanted to make, which wouldn't actually have been a shooter at all. You would have ended up some guy named *Quake* carrying around a massive hammer. It ended up a shooter, of course, an awful lot like *Doom* but in full 3D. But when *Quake* tries to show how big of a deal those state-of-the-art polygons were, it really shines through.

The Wizard's Manse starts with one of *Quake*'s most underused gimmicks: its enemies fighting each other. I walk out onto a long bridge, then immediately retreat back to the cave I started in. I get lucky: an ogre and two Death Knights follow, and a poorly aimed fireball blast into the ogre's back makes him take a chainsaw to the Death Knight instead of me. The bridge and a couple grenade-throwing ogres outside are the manse's lookout tower, and a warm-up for a level that's going to constantly ask you to watch out above.

The manse's main room – I guess criss-crossing walkways over a pool of brown water once passed muster as a foyer? – forces me to skirt the left side of the room until I find a button that raises the right side's walkway. When I leap (OK, fall) into the water to avoid a grenade, I'm rewarded with a few goodies that recover the ammo and health I just lost. It's a quick swim to get back, and also includes a great bit of foreshadowing: a barred-off underwater passageway that I immediately want to find my way into.

One flight of stairs later and I'm under another set of walkways and above another pit of water, but jumping in this time yields something even better: a passageway that leads to a quad damage power-up and a way up, level with the arseholes who were just raining grenades down on my head. The powered-up super shotgun turns them into chunks.





On acid!

The next room is simple, yet one of the most memorable in all of *Quake*: a series of narrow platforms over an acid pit. They pop out of the wall with a thunk when I get close, forming stairs for me to hop up. Finally I'm on the top floor, looking down two levels and wondering if the wizard actually appreciates this view. The graphics in The Wizard's Manse are indistinguishable from the rest of *Quake*, but those little mechanical steps give it character. They make me think about how the wizard gets around his house, and the satisfaction he probably took in building this whole place.

He had a small plot of land, so he had to be creative. It's basically just four rooms – ten minutes of winding and climbing would take about ten seconds laid flat. Usually vertical videogame levels guarantee a groan, at some point, when you fall off the top story and have to walk your way all the way back. But *Quake*'s levels are so dense, that's never a problem. Thankfully there's always a sneaky elevator or alcove that gets you back to where you were in seconds.

Finally, at the end of the level, The Wizard's Manse drops one more *Quake* lesson: in a game all about empowerment, having your power stripped away is more impressive than any new gun.

A glowing button entices me into a cage, which lowers me underwater and into the shaft I saw earlier (aha!), and then slowly carries me down a long passageway. I begin to drown, watching my HP tick away with each choking gasp. It lasts just long enough for me to worry that I've screwed up, and then the cage crests the surface and I can breathe again. Just the kind of contraption a wizard would build to entertain himself and freakout the in-laws. Without a line of dialogue, The Wizard's Manse still manages to tell some little stories.

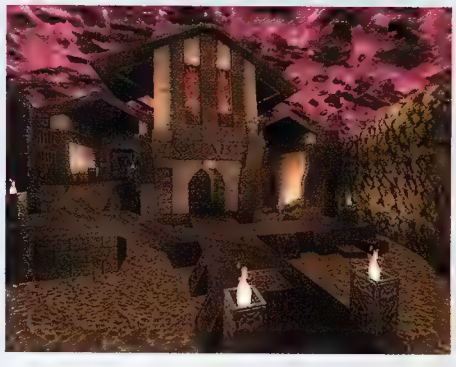
Like magic

The Wizard's Manse isn't a flashy level, but it sets up some of *Quake*'s best ideas to come. The next level, The Dismal Oubliette, closes out episode two with a great centrepiece, an L-shaped bridge that eventually rotates as you progress and find buttons that activate it. At the start, it taunts you with paths you can't take, one holding a tantalising 150 point yellow armour. But

DIMENSIONS OF THE PAST

Anniversary celebrations

Back in 2016, for *Quake*'s 20th birthday, modern *Wolfenstein* developer MachineGames released a new *Quake* episode called Dimension of the Past (or DOPA, which is much funnier). The episode includes nine levels, revisiting *Quake*'s hodgepodge aesthetics from a military base to an ominous mansion. Fingers crossed that *Quake*'s 25th, in June 2021, sees a similar celebration. You can download DOPA here: **cdn.bethsoft.com/quake/dopa.rar**.

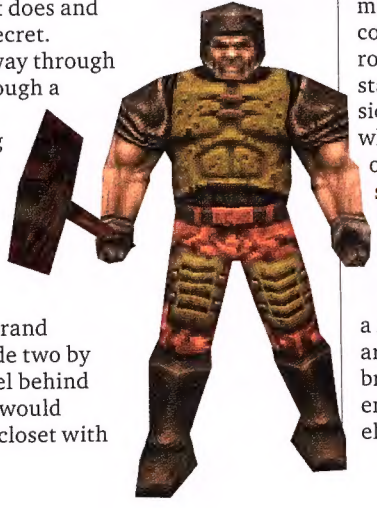


Owwiiee!

there's also armour in the very first room you start on, which means that yellow armour is actually a premonition: you're gonna need that later.

The Dismal Oubliette has just as much fun with medieval contraptions as The Wizard's Manse. Its first room off the centre bridge makes you press a switch to raise a set of stairs out of a pool, and another switch seems like it'll probably rotate that bridge you just left. But no, it actually opens a secret door, the kind you usually have to discover with a shotgun blast to a suspicious-looking wall.

I love when 90s shooters play with the rules of what does and doesn't constitute a secret. Sometimes the only way through a level is actually through a secret room, which heightens that feeling that you're alone in a strange, hostile environment, forging your own path. *Quake* makes The Dismal Oubliette feel like a grand culmination of episode two by hiding half of the level behind the kind of door that would usually just lead to a closet with ammo and armour.



Behind the door lies a whole new area with an intimidating tower (and moat!) in front of you, guarded by a Shambler. In hindsight, hiding all this behind a secret door makes a lot of sense if you know what oubliette means. First-person shooters got a bad rap back in the day, but they must've taught kids at least a few new vocab words, too.

The tower in this level-within-a-level has its own satisfying climb, much like the one in The Wizard's Manse. From the shore across the moat you can see a Shambler pacing back and forth on the top floor. A couple of minutes later, standing over his corpse, you can press a button to rotate the bridge back at the start. Another wall slides to the side to reveal a secret path, which takes you back to the other side of the moat, to a small alcove you probably didn't even notice the first time.

Returning to the centrepiece rewards you with a new route, and the second area that spokes off the centre bridge also sends you up to two enemy-packed floors on an elevator before returning to the ground floor to claim your prize, the final bridge button. The level is spent fighting your way to the top, then earning a breather before you head back to the middle and start again.

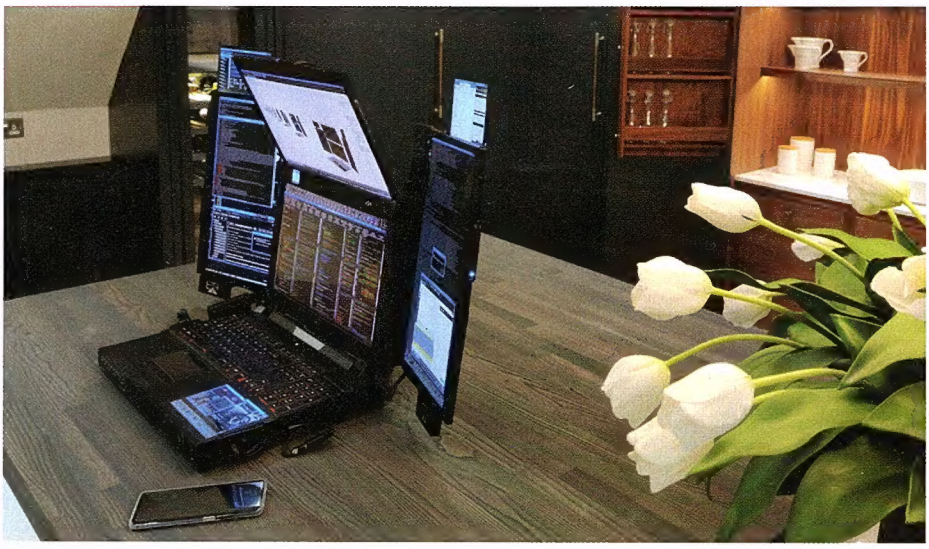
This style of design still exists in games today, but most big-budget shooters are about crossing a larger map and surviving setpieces along the way. Nothing wrong with that, but it doesn't trigger the almost Pavlovian reaction my brain has to closing a loop in a classic shooter, where every accomplishment ends in the revelation that all this time, I was actually just feet away from where I started. It's like a sleight-of-hand card trick: even when I know it's coming, it's still a tiny thrill.

Quake doesn't pull out that trick in every level, but when it does it does it well. It doesn't look so hot in 2021, and the fantasy setting is about as deep as a kid putting on his robe and wizard hat to cosplay. Play a few levels, though, and you'll understand why throwback shooters like Dusk skipped 20 years of progress to go back to *Quake*'s school of level design. It's still a riveting textbook. A textbook with guns.

WES FENLON ■

CHIP CHAT

JOEL BURGESS REPORTS ON THE UNUSUAL SIDE OF TECH NEWS



Expanscape Aurora 7

Run a crypto bullpen on your local Starbucks Wi-Fi with this hepta-screen laptop.

While adding a second screen to your setup is a sure way to improve efficiency and, for some, even a third screen is also a worthwhile addition, there's generally a limit to the amount of screens you need. For the creators of the Aurora 7, that number seems to be seven. Even on a permanent desktop setup, seven screens seems excessive, but the team at Expanscape have taken it a step further by folding them all into a 12kg carbon fibre-encased laptop. Sure, it would be possible to fill those last four screens with your favourite sporting matches or a dank meme feed, but it's a lot of weight for something you could keep on a virtual desktop.

Biden team step in to address processor supply issues

White House says it'll get close to the metal to streamline silicon production.

As the Commander in Chief of the USA, you are responsible for a lot of the world's issues, but one that you probably wouldn't have attributed to the presidency is the smooth manufacturing of computer processors. Nevertheless, the Biden administration volunteered to tackle supply issues in the global semiconductor industry, according to a February statement by the White House Press Secretary Jen Psaki. The issue has become critical for the White House after both General Motors and Ford Motor Co. announced that they would be cutting the local workforce in response to lost profit from an under-supply of processors needed to complete vehicle manufacturing.

Crypto millionaire changing Nevada law to create blockchain nirvana

EARLY BITCOIN INVESTOR DRAFTS LEGISLATION FOR AN INDEPENDENT BLOCKCHAIN BASED STATE.

Jeffery Berns, CEO of Blockchains LLC, is a 60 year old early adopter of digital currencies who bought US$170 million worth of land in the Nevada desert in 2018 to start a new, entirely blockchain-based society. The ambitious futurist, who is a lawyer by trade, is planning the creation of independent, self-sustaining blockchain states called "innovation zones" where companies could replace state authority to oversee and manage the community.

Huawei focuses on pig farming to offset smartphone sales decline

WE GUESS ITS GOTTA BRING HOME THE BACON, SOMEHOW.

US sanctions on Huawei's smartphones have had a major impact on the company's global smartphone sales. In 2019, the US deemed Huawei a national security risk after executives were indicted for evading sanctions on Iran and alleged trade secret theft. While the company denies these allegations, the US banned companies from exporting 5G technology to it. One of the revenue streams Huawei is engaging in to offset the market loss is providing AI technology for pig farmers. AI identification and disease monitoring is potentially big business for Huawei. ■

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